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TR- 69-155 Volume V

Project PIMO Final Report

PIMO Troubleshooting Aid Specifications

PREPARED BY:

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Serendipity Inc.

MAY 1969

Prepared for:

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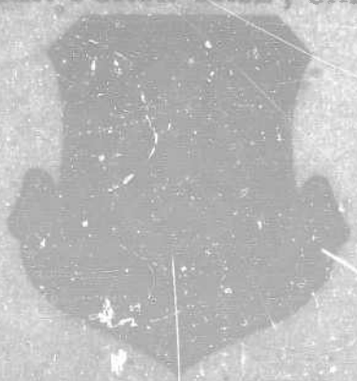

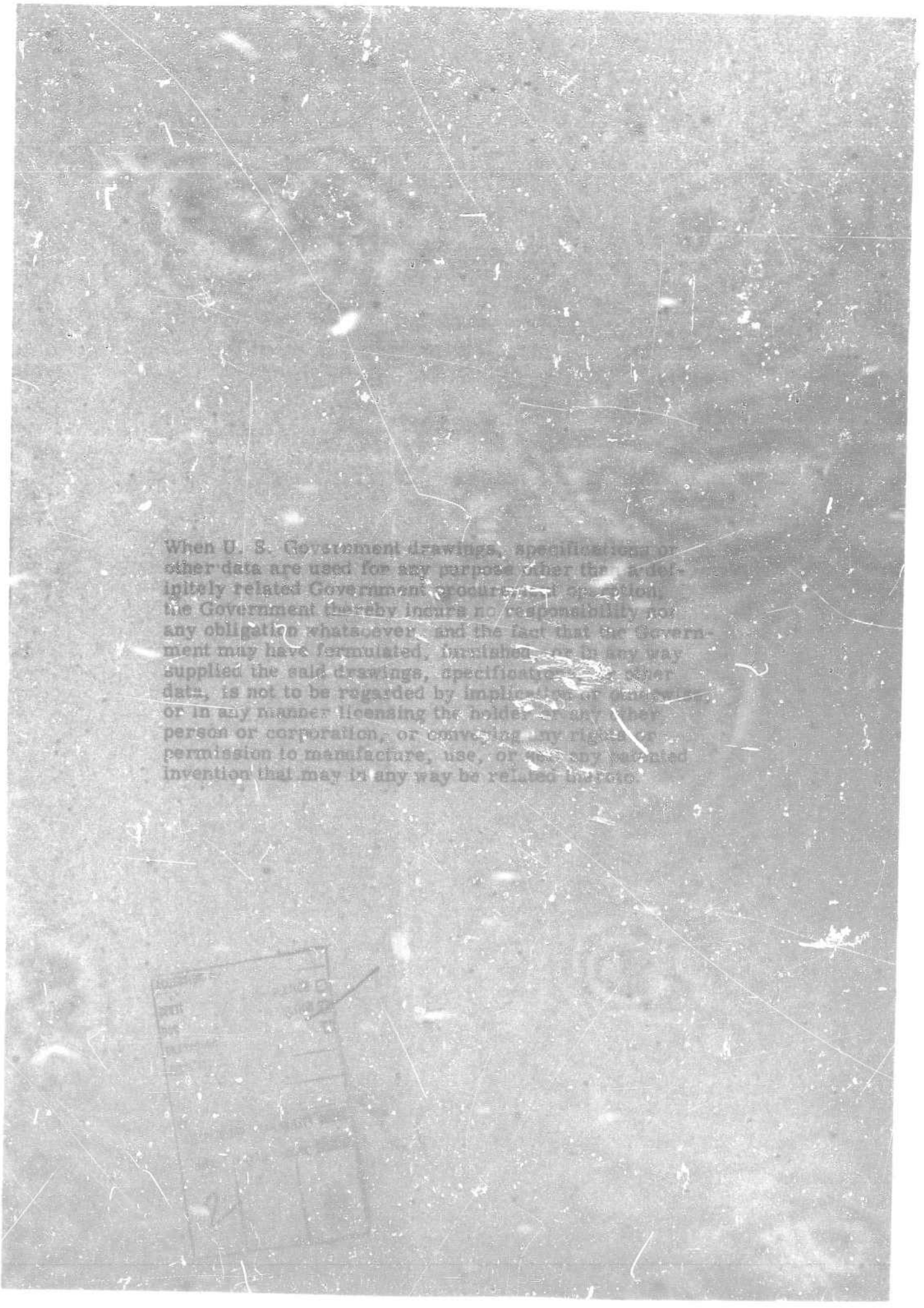

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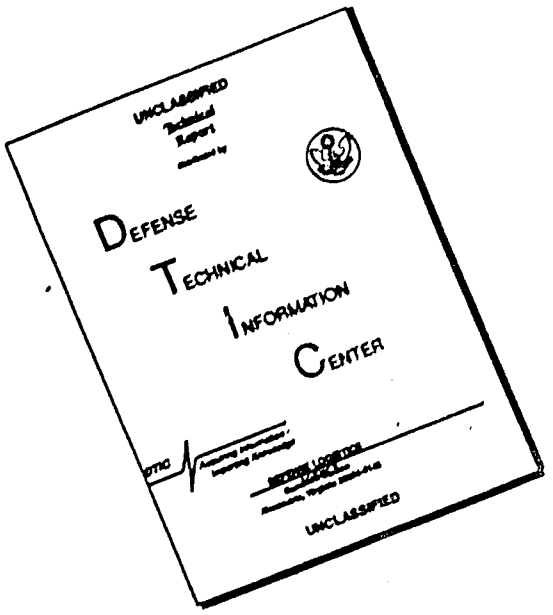

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PROJECT PIMO FINAL REPORT

PIMO TROUBLESHOOTING AID SPECIFICATIONS

PREPARED BY:

Warren H. Straly

SERENDIPITY, INC.

FOREWORD

This report (Volume I through Volume VIII) represents the final phase of a study and test which was initiated in September 1964 to explore newly developed techniques and devices for presenting T. O. (Technical Order) type instructions and information. The eight volumes of data contain the result of a test conducted in an operational environment using concepts developed during an earlier phase under Contract AF 04(694)-729 and documented in BSD-TR-65-456. Both the early phase and final phases which were accomplished under Contract AF 04(694)-984, Project 1316, "Presentation of Information for Maintenance and Operation (PIMO)", were started in June 1966 and completed in April 1969. This final report was submitted in May 1969.

The original program documentation was prepared by Mr. C. L. Schaffer, SMTE, in 1964. He subsequently functioned as the Air Force Program Director and Chairman of a Working Group which monitored all development throughout the life of the project. This Group was composed of individuals from various Air Force commands (AFLC, MAC, ATC, ADC, AFSC) and the Army Command (AMCPM, AXMLE) knowledgeable in the various maintenance disciplines and all facets of the T. O. system. Capt. Don Tetemeyer, the Project Scientist during the formulative stages of the Program was largely responsible for the basic test structure. Mr. John Saunders was the monitor for all contractual aspects until his reassignment in 1968.

Any success one may attribute to the project must be shared by numerous individuals; however, major credit and appreciation are due General Howell M. Estes, Jr., Commander of the Military Airlift Command, who provided the C-141A aircraft and the bases at Charleston, Dover and Norton for the operational test. Sharing in the credit for the MAC contributions are Lt. Col. Don Watt and his staff at Hq. MAC, and Col. Foreman, Col. Henzi, W/O Van Riper and all the personnel at Charleston Air Force Base and also at Dover and Norton who participated in the test. The hardships imposed on their organizations are recognized, and we sincerely appreciate the special efforts put forth to overcome all obstacles. The test could never have been conducted without the cooperation and competent performance of these many individuals.

We are especially indebted to the Air Force Human Resources Laboratory, Wright-Patterson Air Force Base for their financial contributions at a critical point in the project; and also to the Army Materiel Command, who believed the test potential of sufficient magnitude to warrant the expenditure of their funds. We are most grateful for their confidence and assistance. It is most assuredly the primary factor that permitted completion of the test.

This technical report has been reviewed and is approved.

D. A. Cook, Lt. Col. USAF
Hq. AFSC (SCS-2)

ABSTRACT

This report describes the latest phase in the program to develop and evaluate PIMO (Presentation of Information for Maintenance and Operation); a job guide concept applied to maintenance. Between August 1968 and April 1969, a test was conducted at Charleston AFB, South Carolina, to determine the effectiveness of PIMO. Three immediate behavioral effects were expected: 1) reduction in maintenance time, 2) reduction in maintenance errors, and 3) allow usage of inexperienced technicians with no significant penalty. Experienced and inexperienced Air Force technicians performed maintenance on C-141A aircraft using PIMO Job Guides presented in audio-visual and booklet modes. Performance was measured in terms of time to perform and procedural errors. The performance was compared with the performance on the same jobs by a control group, i.e., experienced technicians performing in the normal manner. The following conclusions were drawn from the test results: 1) after initial learning trials, both experienced and inexperienced technicians using PIMO can perform error-free maintenance within the same time as experienced technicians performing in the normal manner, 2) inexperienced technicians perform as well as experienced technicians when both use PIMO, 3) there is no significant difference between audio-visual and booklet modes, 4) the users revealed an overwhelmingly positive reaction to PIMO, and 5) the performance improvements provide the capabilities to significantly improve system performance defined in terms of departure reliability, time-in-maintenance, and operational readiness. This report also presents a description of the recommended operational system, specifications and guidelines for PIMO format development, including troubleshooting.

PREFACE

This report has been prepared under Contract AF 04(694)-984. It partially fulfills the requirement of Contract Data Requirement List (CDRL) Item 29.

It presents the specifications for troubleshooting manuals used for the PIMO field test.

The manuals utilized the Maintenance Dependency Charts (MDCs) of the Symbolic Integrated Maintenance Manuals (SIMMs)*. Integrated (electrical/mechanical) schematics were used in lieu of Precise Access Block Diagrams and Block Text Schematics (which are normally part of the SIMMs package).

Liberal use was made of MCMSP Exhibit 65-1. However, these detail specifications were not constrained by that document.

Experience both in the preparation and use of the manuals has allowed insight into potential improvements. The general format follows the aforementioned exhibit, but recommended changes have been incorporated.

As with most specifications, this document defines the output product with only brief reference to methodology for obtaining the output. Experience has also shown that a "guideline" document would be very useful to personnel who are unfamiliar with creating an MDC.

As an adjunct to this report, such a guideline has been submitted.

PIMO Troubleshooting Aid
Preparation Guidelines
TR 315-69-14(u) Volume VII

Those guidelines are intended to supplement the specifications when the procuring agency feels it is necessary to insure a quality product.

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* See MCMSP Exhibit 65-1; Manuals, Technical and Preventive Maintenance Work Cards, Symbolic Integrated Maintenance Manuals (SIMMs).

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GENERAL SPECIFICATIONS
PIMO
TECHNICAL MANUALS FOR
TROUBLESHOOTING

1. SCOPE

1.1 This exhibit sets forth general requirements for technical manuals to support fault isolation of aerospace equipment and systems. These specifications result from performance under Contract AF 04(694)-984.

2 APPLICABLE DOCUMENTS

2.1 The following documents of the issue, in effect on the date of Invitation for Bids or Requests for Proposal, form a part of this exhibit to the extent specified herein:

SPECIFICATIONS: –

MILITARY

MIL-M-4410	–	Technical Manuals: Title Page, List of Effective Pages, and Reproduction Assembly Sheet; Photolith Negatives; Printing; and Binders
MIL-Q-9858	–	Quality Program Requirements
MIL-M-38730	–	Manuals, Technical: General Requirement for Preparation of

STANDARDS: –

MILITARY

MIL-STD-806 – Graphical Symbols for Logic Diagrams

NATIONAL BUREAU OF STANDARDS: –

ISCC-NBS Color-Name Charts (Supplement to NBS Circular 553)

2.2 The attached illustrations are representative examples of the type of material specified in this exhibit and are included for illustrative purposes only.

3. DATA BASE REQUIREMENTS

3.1 Implementation of this specification requires the existence of, or development of, a technical data base as defined in paragraphs 3.1.1 or 3.1.2.

3.1.1 The data base shall consist of a complete and current set of all technical manuals and technical orders relevant to the system and its end items and basic engineering design data, including design specifications, engineering drawings and illustrations, and analytic data relevant to the system and its end items.

3.1.2 The data base shall consist of a complete and comprehensive task analysis of all maintenance operations relevant to the system and its end items at a level of detail greater than that provided by the Requirements Allocation Sheets of AFSCM 375-5, i.e., at the task element level. The task element data shall be supplemented by basic engineering design data, including design specification, engineering drawings and illustrations, and analytic data relevant to the system and its end items.

3.2 Implementation of this specification requires the existence of, or development of, an inclusive set of system partitions for which technical material for fault isolation will be developed. Guidelines for partitioning have been developed and can be found in Report TR-315-69-14(u), Volume VII, Serendipity, Inc., April 1969.

4. GENERAL REQUIREMENTS

4.1 The security classification requirements of MIL-M-38730 are applicable.

4.2 The notes, cautions, and warnings requirements of MIL-M-38730 are applicable.

4.3 The abbreviation requirements of MIL-M-38730 are applicable.

4.4 For electrical and electronic symbols and reference designations, the requirements of MIL-M-38730 are applicable. For logic diagram symbols MIL-STD-806 is applicable.

4.5 The style of writing shall be terse, tabular, specific, concise and simple. The grammatical person and mood shall conform to MIL-M-38730. When space is restrictive, sentences need not be complete. A clause frequently conveys adequate technical meaning; however, sentences shall not be avoided just to create an engineering level jargon.

4.6 STYLE AND FORMAT FOR MANUALS

4.6.1 Detailed Circuit and Unit Description. Terse form detailed descriptions shall be provided for new or unique circuits or units. For modified standard units or circuits, only the modifications shall be described in detail.

4.6.2 Multiple Manuals. When the thickness of a manual exceeds approximately one-half inch, the manual shall be divided into separate technical data packages to provide easy handling and orderly presentation of material. Each manual, and all pages therein, shall contain the manual and volume number.

4.6.3 Diagram Arrangement. Diagrams shall be arranged in the order of the most general data to the most detailed data.

4.6.4 Layout of Front Matter. All front matter of a 11 x 17 inch manual, as well as other manual material presented in a non-diagrammatic form, shall be arranged left to right, four columns to the page. The first page of a manual shall contain only the title page and list of effective pages. The reverse side of the first page shall be blank and the face shall be numbered "i/(ii blank)" in the lower right hand corner. Table of Contents shall begin on page iii and be arranged in a four column per page format. An index of the total set of manuals shall begin on the following page and be numbered iv. A manual use sheet shall be shown as the last page of the front matter and numbered v.

4.6.5 Other Pages. Other pages of the manual shall be numbered sequentially beginning with the Arabic numeral "1". Even numbers shall be placed in the lower left hand corner of the page and odd numbers shall be placed in the lower right corner of the page. If a page is blank on the back, the printed side shall be numbered, for example, 25/(26 blank).

4.6.6 Numbering of Illustrations and Tables. Illustrations shall be numbered sequentially beginning with the Arabic numeral "1". Tables shall also be numbered sequentially and labeled as figures.

4.6.7 Numbering for Procedures and Checkout Steps. Segmented procedures shall be identified as Step 1, Step 2, etc. Indented checkout steps listed on the Maintenance Dependency Chart shall be lettered sequentially A, B, C, etc.

4.6.8 Use and Change Control. Each page of technical data shall contain identifying titles, dates, effectivity notes, and page numbers for both use and change control.

4.6.8.1 Title. A title of the equipment or system partition, along with the type of data presented, shall appear in the upper outer corner of each page. The equipment or system partition number followed by the title shall appear in bold lettering; for example, 4-1 AILERON CONTROL AND TRIM SYSTEM. The type of data, e.g., Functional Description, shall appear immediately below the title. When multiple pages are required for a given data type, the word (cont) shall follow.

4.6.8.2 Date and Effectivity Note. Each page shall contain the date on which the material was prepared or reviewed and found to be applicable to the equipment or system configuration(s) noted in the Effectivity Note. The model or serial numbers of the equipment or system for which the data is applicable shall appear (with date) in the lower inner corner of each page.

4.6.8.3 Page Numbering. Each page shall be numbered sequentially with Arabic numerals (except front matter where lower case Roman numerals apply) in the lower outer corner. Right hand pages will be odd numbers, left hand will be even numbers.

4.6.9 Type Size and Style

4.6.9.1 Textual Materials. Text shall be prepared in a Roman face (12 point IBM Documentary or equivalent) in cap and lower case, single spaced. On reduced copy final size of characters shall measure no less than 8 points.

4.6.9.2 Diagrams. Call-outs and indices shall be prepared in a Gothic face (12 point IBM Mid-Century or equivalent). On reduced copy final character height shall not measure less than 8 points.

4.6.9.3 Maintenance Dependability Charts. Nomenclature shall be prepared in a Gothic face (12 point IBM Mid-Century or equivalent). On reduced copy, final character height shall not measure less than 8 points.

4.6.9.4 Page Titles. Page main titles shall be prepared in a Gothic face (12 point IBM Mid-Century or equivalent). On reduced copy, final character height shall not measure less than 12 points. Secondary titles shall appear

in a Roman face (IBM Documentary or equivalent) on reduced copy in cap and lower case with a character height no less than 8 points.

4.7 CONTENT

4.7.1 Manuals shall contain the following data, as applicable, arranged in the order indicated, to provide guidance for the fault isolation of the equipment or system partitions to be documented.

Preliminary Information
Maintenance Dependency Chart
Schematic Diagram
Parts Location Diagram
Functional Description

In addition, each manual shall contain front matter to facilitate control over and use of the materials.

4.7.2 The arrangement of presentation of data, as well as the completeness of the information presented, shall be constant, even though the amount of data may vary with the size and complexity of the equipment to be documented. The following paragraphs discuss each of the requirements in detail.

4.7.3 Front Matter. Front matter shall normally be included in the following sequence:

4.7.3.1 Title Page and Cover. The title page shall be arranged in accordance with MIL-M-4410. The cover shall contain the same information without a date.

4.7.3.2 List of Effective Pages. The list of effective pages shall be arranged in accordance with MIL-M-4410.

4.7.3.3 Table of Contents. A Table of Contents shall be prepared to list the types of data and the page number for each specific type of information for each system partition included in the manual.

4.7.3.4 Index to Manual Set. When multiple manuals are necessary for equipment or system fault isolation information presentation, an index to the total set of manuals shall be included. This index shall be arranged alphabetically by equipment or system partition name with a reference to the appropriate manual.

4.7.3.5 Manual Use Sheet. One page of instructions in the use of the manual contents shall be prepared to expedite proper utilization of the materials. These instructions shall be essentially self-explanatory to the manual user and shall include a clear and concise description of new or unique conventions, terminology, and symbology such as those required to use the Maintenance Dependency Charts.

4.7.4 Preliminary Information. Each data set prepared to aid fault isolation within an equipment or system partition should begin with preliminary information sufficient to permit the user to prepare for fault isolation. This information shall include:

Test Equipment Requirements
Personnel Requirement
Equipment or System Condition
Effectivity of Information

The requirements for each information are described in following paragraphs. Refer to page A-1 of the Appendix for an example Preliminary Information Sheet.

4.7.4.1 Test Equipment. A tabulation of all test and ground support equipment required for the checkout or troubleshooting of the equipment or system partition (not normally carried in the standard tool set) shall be presented by name and type, identifying number (AN, part, or stock number), and brief description of the use and application. This tabulation shall be identified as a figure and entitled "Test Equipment".

4.7.4.2 Personnel Requirement. A brief statement on the type of personnel required to conduct an operational checkout shall be included. When more than one man is required, their specific role shall be identified.

4.7.4.3 Equipment or System Condition. The state in which the equipment or system should be in prior to conducting an operational checkout or performing the initial step of the Maintenance Dependency Chart shall be specified. Any new or unique steps required to set up this equipment or system state shall be presented in a procedural format. Any notes, cautions, or warnings shall comply with MIL-M-38730. Any circuit breakers, switches, or controls involved in achieving the initial required equipment or system state may be listed in tabular format. These tabulations may be entitled Functional Circuit Breakers and Preliminary Control Settings and identified as figures. The exact nomenclature appearing on the equipment, its appropriate setting, and its location shall be presented.

4.7.4.4 Effectivity. A summary of the equipment or system model numbers or configurations for which the data set is applicable shall be presented. Engineering Change Procedures or Time Compliance Technical Orders which initiated a configuration change and are included in the data set shall be identified. The preceding effectivity information shall be keyed to the appropriate data items in the data set.

4.7.5. Maintenance Dependency Chart. Troubleshooting information shall be prepared in the form of Maintenance Dependency Charts for each equipment or system. A Maintenance Dependency Chart is a chart which illustrates the dependency and interrelation of all elements and functional entities within the equipment or system by use of symbols. The dependency charts shall provide data necessary to diagnose the equipment. These charts shall conform to the following:

4.7.5.1 By graphic means, show all of the circuit interdependencies in such a manner as to facilitate troublesnooting.

4.7.5.2 Identify all significant checkpoints and indications necessary to troubleshoot the equipment. These must be arranged in a manner which

minimizes the number of checks that a technician must make to isolate a malfunction.

4.7.5.3 Present all signal data (waveforms, timing, voltages, tolerances, etc.) in a manner to facilitate its use in troubleshooting.

4.7.5.4 Relate key troubleshooting to procedural data (adjust, calibrate, turn-on, operation, alignment, and performance check).

4.7.6 Refer to page A-2 of the Appendix for an example MDC. The example shows all of the individual parts, to be explained in following paragraphs, in their total environment.

4.7.7 Layout. The chart shall be laid out in quadrille fashion and shall consist of the following four basic parts: headings, notes, procedure, and body. Column headings list the name and hardware location of functional entities, circuit elements, and event indicators. An event is defined as an action, or the presence of a voltage, signal or other data at a defined point, that results from a turn-on, operational, or checkout procedure, or the presence of initiation data. Notes shall provide specifications and, as necessary, descriptions of the events that occur in the column below. The procedure column shall contain steps, as necessary, which specify the operational or checkout procedure required to obtain all signal availabilities developed as a result of the step. By the use of symbols the body of the chart shall present the relationship between functional entities and events. In preparing this type of chart all circuits of the equipment must be exercised in a manner which permits logical diagnosis.

4.7.7.1 Headings.— Column headings shall list the name(s) and location of the action indicators, availability points, functional entities or circuit elements listed in the column. Events shall include such conditions as: availability of symbols or power units, indicators that may be observed, conditions or states of the equipment, i.e., relay energizes, temperature normal, no overload. Column headings for re-entered signal or voltage availabilities shall identify the chart on which the availability was developed.

"Front Panel" nomenclature shall be used consistently in the procedure and circuit element entries of the Maintenance Dependency Chart.

4.7.7.1.1 Event Entries. – Events shall include conditions as:

(a) Availability of signals or power inputs.

(b) Indications that may be observed.

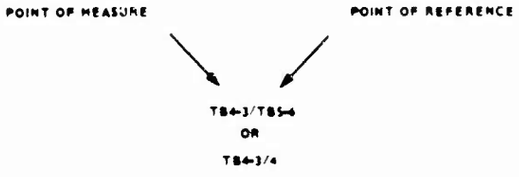
(c) Conditions or states of the equipment; i.e., relay energizes, temperature normal, etc.

Column headings for re-entered signal or voltage availabilities shall identify the chart (or chart part) on which the availability was developed.

4.7.7.1.2 The column headings for indicators of action that are recognizable from the outside of the cabinets, e.g., front-panel indicators or front-panel test points, are solid black with white lettering. All other column headings shall have a white background with black lettering.

4.7.7.1.3 For events which are to be observed, the point of observation is entered as a column heading. When the indication is observable from the outside of the equipment, the panel nomenclature for the indication or a descriptive action identifier is illustrated by white lettering on a black background. This is illustrated as follows:

For events which are to be measured, the points of measure are listed as follows:



4.7.7.1.4 Circuit Element Entries. – Circuit elements or circuit element groupings (functional entity) shall include such items as:

(a) Part of a circuit element.

(b) A circuit element.

(c) A stage or group of circuit elements.

(d) A group of stages.

(e) A replaceable module or group of modules.

4.7.7.1.5 The area above the slanted circuit element entry column is reserved for end-item identification and physical location information (in the extreme top). Assembly numbers, colloquial names, or abbreviations may be used as a reference key Once the location information has been spelled in the heading, it may be abbreviated where appropriate on the remainder of the sheet. In the event that a single circuit element is the end item, no further identification is necessary in the end item entry area. When adjacent columns refer to items in the same assembly, the location identifier can be so placed that it applies to more than one column.

4.7.7.1.6 Specifications or description for the event or action to be observed or measured shall be referenced by a number located in a box at the base of the column heading. The specification numbers at the base of the

column headings shall refer to signal specification notes in the right-hand margin of the chart. The numbers should be independent and sequential throughout all specifications. Specification numbers for each equipment or system partition shall begin with the number one, and identical specifications, i.e., 115V, carry the same number.

4.7.7.1.7 Use of signal specifications data as circuit element entries should not be practiced because it violates the criteria for both circuit element and signal specification entries. In many cases a function of a circuit element is dependent upon specific energy conditions. When this is true, the circuit element should appear in the appropriate column, with a "partial" symbol when it is functional, and a number placed in the signal specifications row to reference the specific energy conditions which appear in the signal specification box. It is permissible to show primary output conditions of one segment as input availabilities on another segment (i.e., Main AC Tie Bus, Hyd Sys No. 1 Pressure, Left Aileron Movement, etc.), since this type of entry represents the main interface area between MDCs. The input condition descriptor may be entered as a circuit element entry; however, the signal specification, tolerance, and description must appear in the signal specification notes.

4.7.7.2. Dependency Notes Table. – A Dependency Notes Table shall list the description, normal reading and tolerance data voltage, or black on white photograph of waveform and tolerance that is associated with each of the indications called for in the box at the base of the column heading. Waveforms shall be retouched only as required to ensure that the pertinent technical information is visible, i.e., rise time, etc. The indication for an event shall be identified by a number identical to the number listed in the box.

4.7.7.2.1 When different aircraft require normal readings and tolerances, that information may be flagged by a triangle with the aircraft designated by a number inside the symbol.

4.7.7.3 Procedure Column. – Procedural steps shall be provided as line headings in the left hand column of the dependency chart. The total of the

procedural steps shall completely exercise each and every functional entity. The procedural steps shall exercise all positions of all switches and each operating control.

4.7.7.3.1 Exercising electronic equipment generally involves switch selections, providing external stimulus, or running diagnostic programs. In any case, the means of exercising the equipment for troubleshooting purposes will determine the structure and organization of the chart.

4.7.7.3.2 Basically, all procedures can be divided into four groups:

(a) Those which must be performed to get the equipment working.

(b) Those which are performed to exercise built-in test devices, meters, etc., which can be performed without any change to the equipment operation.

(c) Those which are performed to break loop circuits or to inject known signals for testing fault circuitry.

(d) Those which are performed to change modes of operation.

4.7.7.3.3 These procedural actions shall take maximum advantage of built-in or ancillary test facilities. They shall also include steps covering portions of the equipment for which no external symptoms are developed incident to malfunction and for which no self-test facility exists.

4.7.7.3.4 Procedures which must be performed for the energizing of the equipment into full operational status shall be numbered sequentially and placed flush left. Procedures which can be exercised as options after an energizing procedural step and before the next energizing procedural step, i.e., mode changes, range changes, and checkout procedures, shall be lettered sequentially within the numbered step and indented. Each procedural step shall be enclosed between bold lines across the body of the chart to indicate events and availabilities which are associated with the procedural step.

4.7.7.3.5 Step numbers shall be continuous from the Primary Power Dependency Diagram through all remaining diagrams to indicate the sequence of events within the complete equipment. Steps on each part of the chart may not be sequential; however, this is preferred.

4.7.7.3.6 There shall be a one-to-one correlation between segmented procedures and steps required for troubleshooting and any procedures developed for operational checkout. This correlation shall provide for direct access to the dependency chart step from the operational checkout step.

4.7.7.3.7 Test equipment, special tools, and materials which are required to accomplish the procedures shall be listed. Recommended items of test equipment, together with suggested alternates, if applicable, shall also be delineated. General purpose test equipment shall not be specified when suitable built-in equipment test facilities are provided. When general purpose test equipment is required the test equipment shall be selected from the list of test equipment approved by the cognizant activity. (See paragraph 4.7.4.1).

4.7.7.4 Body. – The body of the chart shall consist of a series of horizontal lines on which are represented the dependency of circuit action from the performance of a procedural step. Each line will represent a short series path from a signal availability point (test point or other) to an indication, or to a branch point (availability point), directly or through circuit elements, or through functional entities. The lines shall be arranged from top to bottom in order of increasing dependency.

4.7.7.4.1 Each branch point, whether a divergent or convergent branch, shall be identified as a test location (availability point) whether or not a test jack has been provided. Each branch point shall have an availability for the voltage or signal at that branch point.

4.7.7.4.2 Basic Symbols. – Only three basic symbols are to be used to represent the functional entities or circuit elements in the short series paths on the body of the chart:

Evert Box: ☐ to represent an action or availability of one or more events resulting from the proper operation o the functional entities associated with the event.

Functional Entity Dot: ● to represent a functional entity or a group of functional entities.

Dependency Marker: ▲ to indicate dependency upon another event.

4.7.7.4.3 Special configurations of the basic symbols are sometimes used to advantage. Most of the frequently used variations on the three basic symbols are presented in the table that follows (Table 1).

4.7.7.4.3.1 Event Box. Nomenclature in the event box (☐) specifies the type of event and availability of the event. The Definition of Symbols Table lists the various nomenclatures that can appear in the box and their meaning. To assist in determining the accessibility of the events indicated on the Maintenance Dependency Charts, three distinguishable kinds of backgrounds are used within the event boxes. These backgrounds and their use are:

BLACK (with white lettering)  Events which may be recognized from outside the equipment. Examples are: Front panel meters, front panel lamps, PPI display, motor running, etc. Notice that this recognition includes events other than those which may be observed by sight.

GRAY (with black lettering)  Events which may be determined or observed only after the equipment enclosure has been opened, and which are readily accessible. (These events may or may not require the use of test equipment for their recognition.)

CATEGORY	SYMBOL	MEANING
EVENT		Event symbol background indicates ease of access.
		Black: Front Panel, recognized from outside the equipment.
		Cross Hatch: Easy Access, requires opening of equipment enclosure (may or may not require test equipment).
		White: Difficult Access, requires test equipment.
	NA	Signal not available.
	A	Signal available and within specification.
	A1 A2 etc.	Signal available and within specification, but under different procedural condition, or circuit path.
	REM A	Remains available, and within specification, but under different procedural conditions, or circuit path.
	LIT	Front panel indicator lit: filament lit.
		Indicator flashing.
		Motor runs within specification.
	EN	Relay or special purpose switch energized.
	DE	Relay or special purpose switch de-energized.
		Motor stops running.
	etc.	Indicator reads within specification, but under different procedural condition or circuit path.
		Previously lit indicator goes out.
	CLO	Functional entity closed.
	OPN	Functional entity open.
	EXT	Functional entity extended.
	RET	Functional entity retracted.
DEPENDENCY MARKER	▲	Event on same line is dependent upon event or condition in column above proof marker.
	⚠	Event is dependent upon a redundant event or condition in column above proof marker.
SPECIAL NOTE MARKER	①	Special note pertaining to further identification of functional entity.
	⚠	Special note pertaining to aircraft effectivity.
FUNCTIONAL ENTITY	●	Circuit or circuit element that must function properly for event on same line to occur.
	◐	Indicates functional entity requires more than one event to prove proper operation.
	⊖	No continuity through binary element.
	⊖	Continuity through binary element.
	●●	Redundant circuit elements; either will produce event.

Table 1
Definition of Symbols

WHITE [A] Events which are difficult to access and which require the use of test equipment for observation.

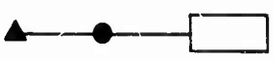
4.7.7.4.3.2 Functional Entity Dot. The purpose of this symbol is to identify the end items involved in signal flow. In some cases it is appropriate to show an availability at a functional entity terminal, but it is still necessary to enter the entity and identify its function relative to signal flow with the appropriate symbol.

4.7.7.4.3.3 Generating availabilities on circuit breakers should be avoided. The circuit breaker should only be identified with a functional entity symbol, and only when it is on-line for the functions affected by the procedure step.

4.7.7.4.3.4 There are several variations of the functional entity dot. One such variation is the partial dot (◐) which indicates that the functional entity is only partially involved in producing the corresponding event. Other variations of the functional entity dot are described in paragraph 4.7.7.4.2.

4.7.7.4.3.5 Dependency Marker. A solid triangle is used to describe the relationship between a group of events and an ensuing dependent event. When any of the multiple events satisfy the subsequent dependency requirement, an open triangle with the letter R shall be used.

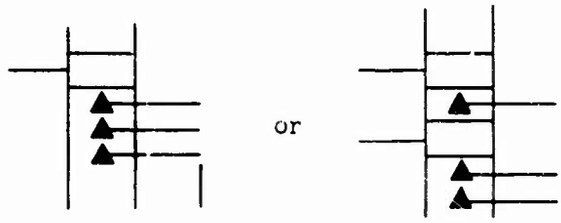
4.7.7.4.3.6 Basic Dependency Structure. – A dependency structure consists of a series of dependency lines. Each dependency line is constructed using the three basic symbols. Each line shall have at least one dependency marker and only (except as provided in 4.7.7.4.3.12) one signal availability. Additionally, symbols to represent the functional entities that develop the signal or event must be included. The simplest dependency line would appear as follows:



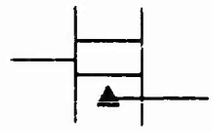
4.7.7.4.3.7 By itself this dependency line has very little meaning except to indicate that the event (▭) is dependent upon the proper operation of the functional entity (●) and the availability of some previous event (▲).

4.7.7.4.3.8 In order to provide meaning to this dependency line the symbols are ordered into one of two types of columns: the event/dependency column and the functional entity column.

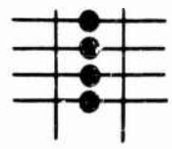
4.7.7.4.3.9 The event/dependency column consists of event boxes and dependency markers depicted as follows:



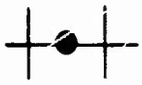
The simplest event/dependency column would appear as follows:



4.7.7.4.3.10 The functional entity column consists of only functional entities, even though these entries may be depicted more than once. It is indicated as follows:



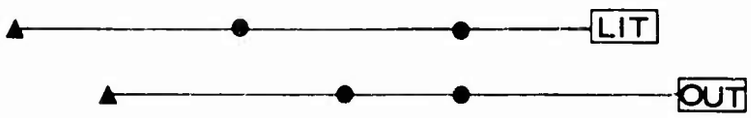
The simplest form of a functional entity column would appear as follows:



4.7.7.4.3.11 When an indicator (or other end item) is used in multiple signal (or energy) paths, enter that end item only once unless it is necessary to do so for transition to another MDC or for clarity of an ambiguous situation.

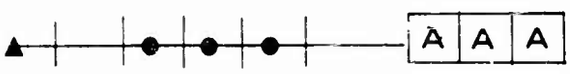
Do:

Don't:

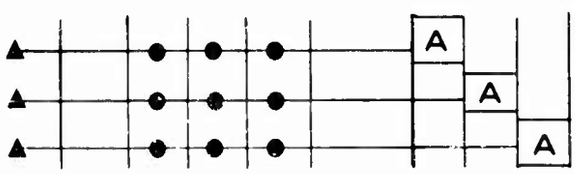


4.7.7.4.3.12 Each line shall have only one event, except for some circuits such as phase-splitters and differential amplifiers which produce two outputs. Thus, when more than one availability or indication results from a signal path, enter the path only once.

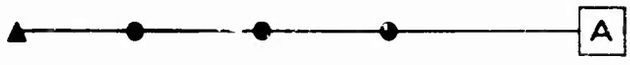
Do:



Don't:



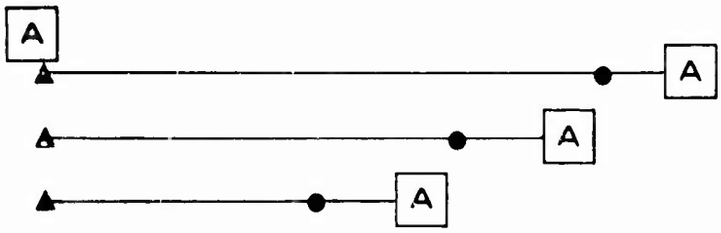
4.7.7.4.3.13 For each short series path, more than one circuit may be necessary.



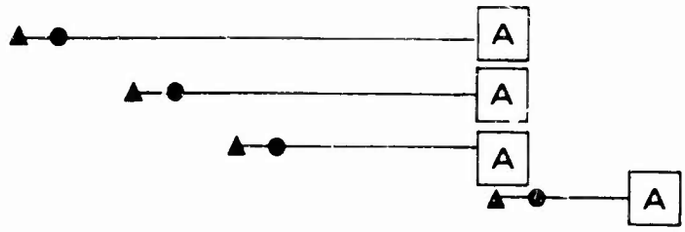
Sometimes long series paths result, such as those found in some I-F strips. Rather than group all of the stages of a long series path on a single line, break the path into two or more short dependent chains. This is true only if a test point is available within the path. Also, when somewhere within a series path a significant change in the signal occurs, generate an event box upon which the remainder of the series path is dependent. These techniques provide better and faster fault isolation.

4.7.7.4.3.14 For each short series path, more than one dependency may exist.

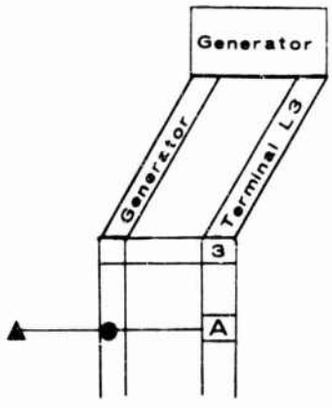
4.7.7.4.3.15 Parallel divergent branches appear as follows:



4.7.7.4.3.16 When any of the inputs operate a following circuit, parallel converging branches appear as follows·

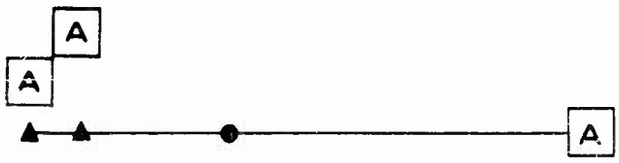


4.7.7.4.3.17 When a higher order system (black box) is required to function in the circuit to produce the availability of an end item comprising that system, the black box should be entered as an entity. An example is illustrated below where operation of the generator is required to produce a signal at winding terminal L3. In this example, the generator is the circuit element required to convert the energy from the dependency (shaft rpm) to the availability (115 vac) at an accessible test point (terminal L3). The partial symbol indicates that this path does not completely validate generator operation.

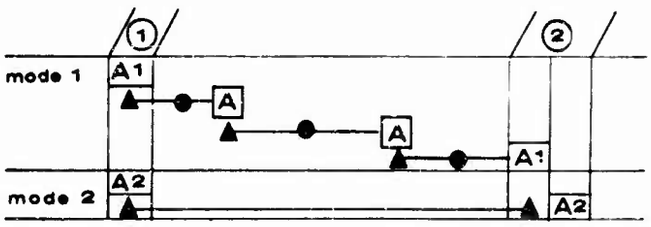


4.7.7.4.3.18 Selectable Points. – When certain signals interspersed through a system are selectable by a switch, relay, or other means, a special application of the technique for parallel converging branches is used to monitor a number of selected signals. Each line resulting from one of the states of selection must be entered immediately following the availability entry for the signal selected. Together these lines distributed vertically throughout the dependency chain terminate with several indication events in the single column of the readout device. One example of this is the multiple use of one meter to monitor a number of selected signals.

4.7.7.4.3.19 When all of the inputs are present or available to operate the following circuit, parallel converging branches appear as follows:



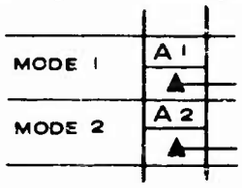
4.7.7.4.3.20 When a complex dependency chain produces an event which proves a group of functional entities good under one mode of operation, it may be proven good under another mode as follows:



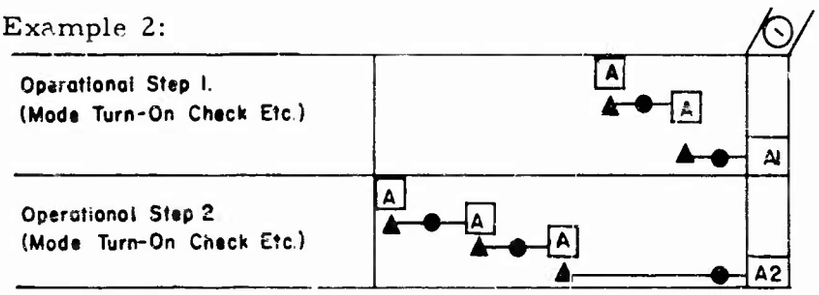
The two events above (farthest to the right) are measured at the same physical test point, but charted in two adjacent columns containing the same signal specification number. The last line is interpreted as follows: If A2 at is now available, and if A1 at was available during Mode 1, then A2 at is available for Mode 2. This implies that all functional entities required for Mode 1 are also necessary for Mode 2. This technique eliminates the need for redeveloping the entire dependency chain of Mode 1 again for Mode 2.

4.7.7.4.3.21 A second case occurs when two events of different operational steps occur at the same measurement point, but are a result of different dependency chains. The following two examples illustrate this situation.

Example 1:

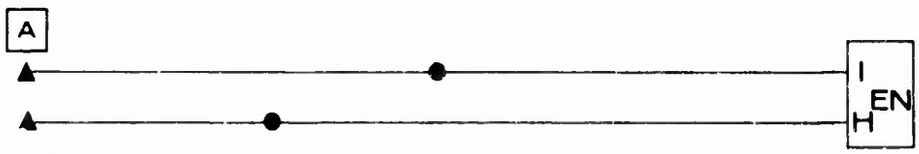


Example 2:



4.7.7.4.3.22 A variation of the functional entity dot is the open circle containing a line within it. This symbol represents a circuit element which can assume one of two states. The symbol indicates continuity; whereas, the symbol indicates discontinuity. This variation on the circuit dot shall be used for entities of a binary nature. An example is a set of relay contacts. Another example is a hydraulic valve.

4.7.7.4.3.23 When relays are held energized by a separate path from the initial energizing voltage, a converging situation exists and is shown as follows:



4.7.7.4.3.24 All initial input conditions are entered on the first line of the chart. Inputs are generally grouped at the left side of the chart. Events are generally grouped at the right side of the chart. Initial conditions such as "Cabinet Temperature Normal" are included as appropriate in the dependency scheme.

4.7.7.4.3.25 Dependency chains for test circuits and their associated check-out procedural steps are entered on the line or lines immediately following the entry of the generated signal availability or event to be tested.

4.7.7.4.3.26 Other troubleshooting charts may require the availability of a signal that is generated on this sheet. For easy access to this availability from the other troubleshooting chart (or from another sheet of the same dependency chart) it shall be located at the right of the MDC and is referred to as an End Distribution Point. Enter the availability point where it would normally occur (only if a dependency marker appears in that column) and repeat the availability symbol as far to the right as possible to provide each access from other parts of the dependency chart.

4.7.7.4.3.27 Protective time delays which occur after a procedural step is initiated shall be illustrated by placing a band of screen shading horizontally across the page immediately after the entry of the time delay device. Time is assumed to begin with the setting of the switch that initiates the step in which the time delay occurs. The length of the time delay is indicated within the shaded band. When the time delay is not directly related to the step, special notations may be added within the time delay band, e.g., "2 seconds after motor exceeds 3000 rpm."

4.7.7.4.3.28 When isolation to a replacement module, e.g., printed circuit card, etc., is dictated by the maintenance philosophy of the equipment, a Maintenance Dependency Chart is prepared to illustrate the functional interrelation of the modules. The chart is prepared in the same manner as other Maintenance Dependency Charts. The module is represented as a dot.

4.7.7.4.3.29 When a module is multifunctional, identification of the signal path within the module will facilitate the development of dependency paths necessary for fault location by less skilled personnel. This identification will require additional end-item entries for the module at a level lower than the overall module. This connection reduces the requirement to refer to the

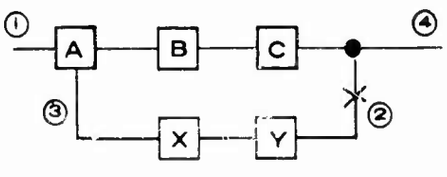
schematic of the circuit in which the module is an element.

4.7.7.4.3.30 When the module contains more than one circuit and receives more than one input signal and/or generates more than one output signal, a partial dot is used to illustrate partial proof. The partial dot is referred to as an "aspect" symbol indicating some aspect of the circuit involved must be good. The partial dot can be used for multiple throw switches to conserve circuit element entry space, particularly when the schematic provides switch continuity information.

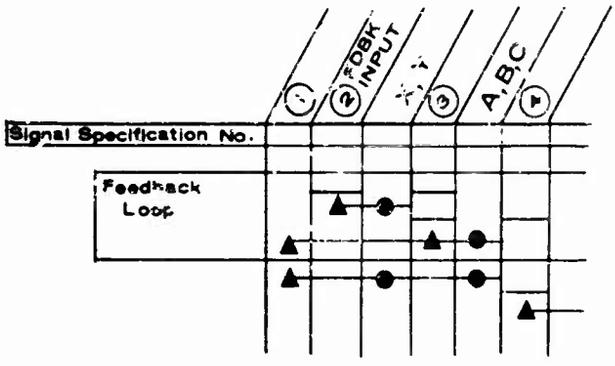
4.7.7.4.3.31 When the output of a circuit is sent back to appear as part of the input to the circuit, a feedback loop exists. To disclose the functional dependency of such a loop requires that the loop be broken. Under these conditions, the normal (main) input into the loop, plus a proper stimulus inserted at the break, will result in a known output. Breaking the loop allows functional dependency to appear as a simple serial dependency chain.

4.7.7.4.3.32 Feedback loops are identified in the procedure column and enclosed in a manner similar to checkout steps (refer to example, Feedback Block Diagram and Maintenance Dependency Chart below). The complete dependency structure of the broken loop is then shown within the enclosed area. Directly below the enclosed area, the dependency structure of the loop is again shown but with the loop connected as normal. This structure appears as a horizontal line consisting of a dependency marker, a series of dots and an output. In other words, the line shows that if the input to the loop is available and all functional entities within the loop are good, then the output of the loop is available. Using this technique, the detailed dependency structure of a feedback loop can be disclosed while also showing how the loop as a whole fits into the general dependency scheme of the MDC when normally connected.

Feedback Block Diagram



Maintenance Dependency Chart



Signal Specifications
1. Waveform Data 2 Feedback Waveform Data 3 Waveform Data 4. Waveform Data

4.7.7.4.3.33 When the troubleshooting channel for a function cannot be prepared as a single page, discrete subfunctional groups may be illustrated as separate charts on a following page. The use of this separate page is limited to necessity and must not be used simply for convenience.

4.7.7.4.3.34 Mechanical systems such as gear trains, etc., follow energy relationship laws as do electrical or hydraulic energy flow systems. Such mechanical systems shall be depicted and charted in the same manner as electrical or hydraulic systems.

4.7.8. Schematic Diagram. A schematic diagram is a graphic representation showing the interrelationship and maintenance significance of each component or group f components (referred to as functional elements) in a given part of the equipment or system partition. The partition shall be represented by an integrated schematic combining electrical, hydraulic, and mechanical entities into a single composite schematic. This requirement is based upon the desire to present the overall picture of the equipment or system partition where this partition is defined as a closed-loop system implementing a functional requirement. The items comprising this system may belong to various hardware classes. Refer to page A-3 of the Appendix for an example schematic.

4.7.8.1 Arrangement. The arrangement of the elements on the schematic shall be such as to best facilitate its use. Circuit elements shall be grouped into functional entities, then the functional entities should be arranged on the page to make the signal flow obvious (generally from left to right). Feedback signal flow will generally be from right to left. This requirement should not be allowed to constrain arrangement to the point where components must be repeated, excessive line crossings are needed, etc. Arranging circuit elements to "fill up white space" or to "maintain tube alignmert" for esthetic purposes shall be avoided. Circuit elements shall be arranged in the familiar textbook form. Layout shall not be distorted to achieve fit.

4.7.8.2 Layout. The schematic shall be configured to permit signal tracing, to identify functional entities by name and alpha-numeric designator, and to show the location of all functional entities.

4.7.8.2.1 Functional Circuits. Circuit elements shall be grouped into functional entities according to the following rules (when applicable):

4.7.8.2.1.1 Circuit elements or groups of elements which work together to perform some system function shall be grouped to form functional entities, e.g., amplifier, emitter follower, etc.

4.7.8.2.1.2 Groups of functional entities which work together to provide some discrete system function and which cannot be described adequately or troubleshot separately at a system level shall be composited into a more general functional entity, e.g., voltage regulator, stagger-tuned IF amplifiers, etc.

4.7.8.2.1.3 Basic grouping shall consist of the least number of circuit elements which perform a discrete function, e.g., amplifiers, resistive or capacitive dividers, etc. Functionalization shall be subordinate to conventional presentation of a specific circuit, e.g., the bias divider for a transistor amplifier shall not be shown separately but shall be included in the amplifier groupings.

4.7.8.2.1.4 Interstage coupling shall be assumed to be part of the input to a stage. However, transformer coupling shall be assumed to be part of the output of the stage.

4.7.8.3. Symbology. Conventional engineering symbology shall be used in schematic preparation. Conflicts in symbology between prime contractor-furnished schematics and subcontractor-furnished schematics shall be minimized. A list of symbols is a necessary part of the troubleshooting aid manual; therefore, all peculiar conventions shall be noted. In certain instances, pictorial representation of end items will help provide a more meaningful grasp of the system. In other cases, it may be desirable to present a schematic with some sections illustrated in greater detail than others.

4.7.8.4. Functional Entity Identification. The schematic shall identify all functional entities and interconnecting circuitry by:

(a) Alpha-numeric code designator

(b) Conventional name or nomenclature

(c) Location

Each unit, assembly, or subassembly which has a military designation, or other identifying number shall be identified as follows: Reference designations shall be printed adjacent to the symbol or pictorial which represents the hardware and the designators are followed by its official nomenclature. Reference designations for multiple use assemblies shall be identified by flag note and an associated note-table.

4.7.8.5 Interconnects. Interconnecting elements such as electrical wiring and hydraulic piping shall be identified. Connectors, plugs, terminal boards, and similar elements shall carry an alpha-numeric code designator.

4.7.8.6 Signal Names. Signal names shall be provided for each connection into and out of the line removable functional unit. Wires with signals that mate with the unit, but which are not used in the unit, shall be labeled "no connection" on the inside of the unit. Signals generated in the unit which connect

to plugs, but which are not used in illustrated functions, shall be labeled "not used".

4.7.8.7 Adjustments and Controls. Nomenclature for front panel adjustments, controls, and test points shall appear in reversed lettering (white upper case letter on a black background) on the schematic. If no nameplate designator is provided on the equipment or system, the identification shall be descriptive.

4.7.9 Parts Location Diagram. A parts location diagram showing the relationship of equipment or system partition parts shall be provided to support the schematic diagram, as applicable. The parts location diagram shall identify functional unit particulars not included on the schematic diagram required to expedite troubleshooting. Refer to page A-4 of the Appendix for an example parts location diagram.

4.7.9.1 Arrangement. The parts location diagram shall illustrate end items in the relationship in which they appear in the physical equipment or system.

4.7.9.2 Layout. Diagram shall show at least one view of the equipment or system end items in such a way as to permit recognition of the physical element from the pictorial representation. Tabular listings shall be placed either below or to the right. Judgment of the illustration area which favors effectiveness of communication of information rather than artistic balance shall apply. Enlarged views of sections of the diagram may be employed for purposes of identification. The identification markings shall agree with the identification included in other data types.

4.7.9.3 Photographs and Line Art. Photographs may be used except for parts which are mounted in areas which are inaccessible for photography. Line art (preferably edited engineering drawings) shall be used where photographs cannot be obtained. A balloon-leader callout method shall be employed to orient partial line art or partial photographs used to highlight areas of importance within the main illustration.

4.7.9.4 Equipment or System Parts Location. To adequately describe the location of the equipment or system elements relative to the overall system, the illustrated partition shall be keyed to a general level representation of the total system. The isolated elements shall be identified by letter designators following an alphabetical progression commensurate with signal flow. Each functional unit shall be identified by an Arabic numeral and keyed to a list giving proper alpha-numerical designators and nomenclature.

4.7.10 Functional Description. A complete description of the technical aspects of the equipment or system partition shall be provided. The technical functional description shall be terse, technically complete, and accurate. The functional description is intended for the following purposes:

(a) Support the formal training courses on the subject equipment;

(b) Support on-the-job training;

(c) Provide adequate technical detail to support a qualified maintenance technician in his maintenance job;

(d) Provide adequate technical data for an operator or a technician, qualified on similar equipment, to self-train.

Discrete information segments shall be disclosed by paragraphing. A new paragraph shall be initiated with each new information topic. Refer to page A-5 in the Appendix for an example.

4.7.10.1 Content. The manual shall include an overall description and purpose of the equipment or system. This information is intended for use by personnel who require a general summary of the equipment or system as a whole, and of its interrelated units. The functional description shall describe the intended use (why, where, when, and with what), capabilities, and limitations of the equipment or system. Text covering physical descriptions or structural arrangements shall be brief, with special attention given to avoiding

the inclusion of unnecessary or repetitious details that are easily illustrated. If the manual covers more than one model of equipment or system -- or equipment or systems modified by time compliance technical orders -- a statement or table pointing out the differences shall be provided. Where a statement or table is not adequate or becomes cumbersome because of the complexity of a modification, reference shall be made to an appropriate government document which delineates the differences. A list of equipment supplied, together with the approximate volume, weight and center-of-gravity, and over-all dimensions of each unit or cabinet, if applicable, shall also be included. Quick reference data shall be included and shall consist of pertinent technical or design characteristics of the equipment. Examples of such data are:

(a) Descriptive (nameplate) data necessary to identify manufacturer, type, and model.

(b) Functional characteristics, such as:
- Power requirement
- Injection type
- Types of operation
- Power output
- Frequency
- Pulse characteristics
- Sensitivity; selectivity

(c) Capabilties, such as:
- Rated ranges
- Speed
- Coverage
- Resolution
- Accuracy

(d) Rated outputs, such as:
- Wattages
- Voltages
- Horsepower

Gallons per minute
Thrust
Torque
Footcandle or lumens

(e) Special characteristics, such as:
Operating temperatures
Heat dissipation per unit
Pressure
Humidity
Tolerances

4.7.10.1.1 Equipment or System Partition. A general description of the overall functional performance shall be presented, identifying lower level equipment or system requests as required, to include:

(a) Commonalities with other similar equipment performances.

(b) Characteristics unique to this particular equipment design.

(c) The interrelationship of the equipment being described with other interfacing equipment or system partitions in terms of energy or signal.

4.7.10.1.2 Equipment or System Segments. A more specific functional description of any lower level partitions within the overall equipment or system partition shall be provided.

4.7.10.1.3 End Items. Functional descriptions of the end items shall be concerned with the following:

(a) Unique physical characteristics not obvious in the parts location diagram.

(b) Unique performance characteristics that distinguish the end item from other similar end items.

(c) Interrelationship of end items that mechanize the equipment or system performance.

4.7.10.2 Format. The requirements of MIL-M-38730 are applicable. The following paragraphs specify additional requirements for the functional description format.

4.7.10.2.1 Wording. The text shall be factual, specific, concise, and clearly worded so as to be readily understandable to relatively inexperienced personnel performing the work on the equipment, yet provide technicians with sufficient information to insure peak performance of the equipment. The sentence form shall be simple and direct, avoiding the obvious and the elementary, and omitting discussions of theory except where essential for practical understanding and application, or as required by the applicable detail specification. Engineering knowledge reflected in the manual shall first be converted into the most easily understood wording possible. Technical phraseology requiring a specialized knowledge shall be avoided, except where no other wording will convey the intended meaning.

4.7.10.2.2 Grammatical Person and Mood. The third person indicative s' all be used for description and discussion; for example: "The torsion link assembly transmits torsional loads from the axle to the shock strut."

4.7.10.2.3 Paragraphing. The first paragraph in the functional description shall be titled "General", and contain a general description of the functional unit. The lower level segments, or principle end items, should be identified in this paragraph. The second paragraph shall describe the normal operation of the functional unit, from the input source through the end items to the output. The remaining paragraphs in order of presentation shall be concerned with alternate operational mode descriptions, segment descriptions, and end item descriptions. Each paragraph should be titled with the name of the operational mode, segment, or end item with which the description is concerned.

The complete title shall appear in upper case letters, with the descriptive paragraph starting on the same line. No paragraph numbering is required. Where appropriate, the figure number of art work that supports the discussion should be immediately referenced in parentheses.

4.8.10.2.4 Supportive Art. The text shall be supported by illustrations. Illustrations shall also be used when required by the applicable detailed specifications to furnish pictorial identification of parts and tools. The minimum number of illustrations essential for such purposes shall be used. Illustrations serving no specific instructional function shall not be used. Illustrations that are duplicates in appearance and content of an illustration appearing elsewhere in the same manual shall not be used. An illustration shall not be used which is altered in appearance by rearrangement but contains no different information. Titling duplicate illustrations differently does not license the use of the same illustration more than once in the same manual. Use of illustrations in the functional description shall be limited to providing additional detail not appropriate to parts location or schematic illustrations. Figures appearing in the functional description shall be identified by the equipment/system partition number, followed by a dash and the Arabic numerals progressing from "1", and shall be located as close as possible to the paragraph they support.

4.7.10.2.5 Columnar Arrangement. The text of the functional description shall be arranged in columns such that two columns would appear on a page 8-1/2 inches wide. A page 17 inches wide would permit four columns, and a page 35 inches wide would permit six columns.

4.8 REPRODUCIBLE COPY, NEGATIVES, PRINTING AND BINDING

4.8.1 Typography. The requirements of MIL-M 38730 are applicable.

4.8.2 Layout. Recommended layout shall be a function of the equipment to be documented. For complex equipment, the following maximum page sizes of manuals shall apply.

Page Size 11 x 17 inches
Image Area 10 x 16 inches
Binding along the 11 inch edge
Binding Edge 5/8 inch

All final page sizes shall be within ± 3/32 inch of above specified size.

4.8.3 Illustrations. Illustrations shall be prepared to result in clear, legible illustrations.

4.8.3.1 Lettering. Lettering typography shall be as set forth in MIL-M-38730.

4.8.3.2 Continuous-tone Artwork. Continuous-tone artwork (photographs and renderings) shall provide a clear definition of shapes, tonal values, and surface texture. Photography shall be well lighted, commercial quality. Retouching shall be held to a minimum; it shall be used only to enhance the technical detail of the photograph. Retouching to remove scratches on the equipment or for appearance purposes alone should be minimal.

4.8.3.3 Line Artwork. Line artwork shall be prepared with line weights of sufficient strength to reproduce sharply and clearly at the final reproduction size. Layout shall be determined by a technical authority to communicate technical information graphically, to preclude the necessity for explanatory words. In laying out Maintenance Dependency Charts, a double weight vertical line forming the first line of a column shall be used each time a represented data flow path leaves an assembly or enclosure cabinet and enters another. The boxes that enclose procedural steps and checkout steps shall be made using double weight lines.

4.8.4 Negatives. Negatives used to produce plates for the printing of each page shall be register-marked, free of defects, opaqued, free of pinholes and crop markings.

4.8.5 Printing. Technical manuals shall be reproduced by the offset process. Covers may be prepared using silk screen process. Letters, lines, and symbols shall be uniform contrast throughout the final printed material. Blurred or smudged printing or drop-out of characters, lines, or letters, or failure to meet the other requirements of this paragraph shall be cause for rejection of the final manuals.

4.8.5.1 Drilling. Manuals shall be drilled to accommodate metal multi-ring (19) binding. Holes shall be drilled not less than 1/2 inch from 11 inch binding edge and shall not be through any illustration image area.

4.8.5.2 Binder. Centered across the 17 inch dimension on the face of the cover shall be the main title from the title page, less the date. The back of the front cover, and both sides of the back cover shall be blank, unless the manual is classified. In the latter case, the back of the back cover shall show the security classification centered at the top and bottom.

4.8.5.3 Page Stock. The requirements of MIL-M-4410 are applicable.

4.8.5.4 Cover Stock. Cover stock shall be of plastic, Lexide, or equivalent. Information to be imprinted on the cover shall not be stamped in gold or any other metal foil. Cover color shall be blue.

4.8.6 Binding. Manuals shall be prepared in looseleaf form to facilitate the insertion of replacement pages. Commercial, hinged metallic multi-ring fasteners are to be used.

4.9 CHANGES AND REVISIONS

4.9.1 Changes and revisions shall conform to MIL-M-38730.

4.9.2 To facilitate changes and revisions in a timely fashion the supplier shall have an indexing system for basic technical data that permits ready insertion of changes in basic technical data and output of indicated changes required in the technical manuals.

5. QUALITY ASSURANCE PROVISIONS

5.1 RESPONSIBILITY FOR INSPECTION

5.1.1 The supplier is responsible for performing all inspections required to assure compliance with this specification, and to assure that the required technical manuals are in all respects technically in agreement with the actual equipment or source data. The supplier shall have a quality assurance plan and controls in accordance with MIL-Q-9858A. The government reserves the right to perform any inspections that are considered by the government to be necessary to assure conformance to the requirements of this specification.

5.2 REVIEW, VALIDATION, AND VERIFICATION

5.2.1 The supplier shall perform the review and validation requirements as outlined in T.O. 00-501, and certify the technical manuals do, in fact, reflect the actual equipment or source data. The government, thereupon, shall perform a verification of those technical manuals against the actual equipment or source data. Any errors found during this verification shall be corrected by the supplier. Furthermore, if more than 5% of the total number of pages containing technical data (e.g., drawings, sketches, technical exhibits, tables, tear-down or assembly procedures, etc.) have discrepancies or omissions thereon, that particular manual(s) shall be rejected by the government. It then shall be screened by the supplier at no additional cost to the government, and necessary corrections made by the supplier, and then resubmitted to the government for verification under the same acceptance criteria. In addition, all errors found by the government during verification shall be corrected by the supplier at no additional cost to the government. Finally, the supplier shall warrant the conformance of the technical manuals to the actual equipment or source data in the configuration

existing on the date of publication, for a period of 18 months from date of publication.

6. PREPARATION FOR DELIVERY

6.1 PACKING

6.1.1 Packaging, packing, and marking for shipment shall be in accordance with MIL-M-38730.

Figure 1. Test Equipment

NAME	AN, PART, OR STOCK NO.	USE AND APPLICATION
CONTROLS SYSTEM RIGGING KIT	3500009 (LOCKHEED NO.)	KIT INCLUDES AN INCLINOMETER FOR MEASURING ANGLES.
GAUGE, PUSH-PULL DIAL	DPP-50 (CHATILLON NO.) OR 6635-578-5286 TORQUE WRENCH (50 to 400 INCH POUND RANGE)	TO MEASURE FORCES REQUIRED TO ROTATE THE CONTROL WHEEL.
GENERATOR SET	6115-553-8957, 6115-653-5595, OR 6125-669-6754	TO ENERGIZE ELECTRICAL CONTROL CIRCUITS.
HYDRAULIC TEST STAND	4920-670-9415 OR 4920-615-4248	TO PRESSURIZE NO. 1 AND NO. 2 HYDRAULIC SYSTEMS.
TESTER, SPRING RESILIENCY, PORTABLE (MODEL L-10)	6635-550-6496	TO MEASURE BREAKAWAY AND FRICTION FORCES AT THE CONTROL WHEEL.
TESTER, COMPRESSION AND TENSION (MODEL L30-M)	6635-578-5286	TO MEASURE CONTROL WHEEL OPERATING FORCES OF 10 TO 30 POUNDS.
TENSIOMETER	6635-530-1128	MEASURING TENSION IN CONTROL CABLES.
MULTIMETER	AN/PSM-6	MEASURING VOLTAGES AND CONTINUITY.

PERSONNEL REQUIRED

TWO MEN WITH INTERCOMMUNICATION SETS ARE REQUIRED TO TROUBLE-SHOOT AILERON CONTROL AND TRIM SYSTEM. STATION MAN A AT FLIGHT STATION TO OPERATE CONTROLS. STATION MAN B AS REQUIRED TO OBSERVE MOVEMENT OF AILERON CONTROL SURFACES AND LINKAGES, AND TO MAKE NECESSARY RIGGING CHECKS AND CONTROL SURFACE MEASUREMENTS.

EQUIPMENT CONDITION

1. AIRCRAFT MUST NOT BE ON JACKS AND FUEL TANKS SHOULD BE LESS THAN HALF FULL.
2. RESERVOIRS FOR NO. 1 AND NO. 2 HYDRAULIC SYSTEMS MUST BE PROPERLY SERVICED.

CAUTION

IF NO. 1 AND NO. 2 HYDRAULIC SYSTEMS HAVE HAD RECENT CORRECTIVE MAINTENANCE, THEY MUST BE BLED AND CHECK OPERATED ACCORDING TO THE CORRESPONDING CHECKOUT PROCEDURE.

CAUTION

IF AILERON POWER CONTROL ASSEMBLIES HAVE BEEN INSTALLED RECENTLY OR HAVE BEEN INOPERATIVE FOR A LONG TIME, BLEED THE VALVE DAMPER ASSEMBLIES ACCORDING TO SERVICING INSTRUCTIONS FOR POWER CONTROL ASSEMBLY SERVOVALVE DAMPER.

3. ROTATE PILOT'S CONTROL WHEEL TO NEUTRAL POSITION AS INDICATED BY INDEX MARKS ON WHEEL HUBS ALIGNED WITH SCRIBE MARKS ON TOP OF CONTROL COLUMNS.

CAUTION

ENGAGING OR DISENGAGING THREE PHASE CIRCUIT BREAKERS WITH THE ELECTRICAL SYSTEM ENERGIZED COULD RESULT IN DAMAGE TO MOTORS BY OVERLOADING ONE OF THE MOTOR PHASES. ALWAYS VERIFY THAT ELECTRICAL POWER IS OFF BEFORE ENGAGING OR DISENGAGING CIRCUIT BREAKERS THAT APPLY UNSWITCHED POWER DIRECTLY TO THREE PHASE MOTORS.

4. ASSURE THAT CIRCUIT BREAKERS LISTED IN TABLE 4-1B ARE CLOSED.
5. ASSURE THAT SWITCHES ARE POSITIONED ACCORDING TO TABLE 4-1C.

Figure 2. Functional Circuit Breakers

CIRCUIT BREAKER NAME	BUS	FLT. ENGR. CRT. BKR. PNL
HYD SYS NO. 3 PUMP NO. 1 PWR PHASE A	MAIN AC NO. 1	NO. 1
HYD SYS NO. 3 PUMP NO. 1 PWR PHASE B	MAIN AC NO. 1	NO. 1
HYD SYS NO. 3 PUMP NO. 1 PWR PHASE C	MAIN AC NO. 1	NO. 1
HYD SYS NO. 3 PUMP NO. 2 PWR PHASE A	MAIN AC NO. 3	NO. 1
HYD SYS NO. 3 PUMP NO. 2 PWR PHASE B	MAIN AC NO. 3	NO. 1
HYD SYS NO. 3 PUMP NO. 2 PWR PHASE C	MAIN AC NO. 3	NO. 1
AILERON TRIM CONT PHASE A	ESSEN AC NO. 1	NO. 2
AILERON TAB ACTR LH	ISOLATED DC	NO. 3
AILERON TAB ACTR RH	ISOLATED DC	NO. 3
WARN LT TEST & ANNUN CONT NO. 1	ISOLATED DC	NO. 3
WARN LT TEST & ANNUN CONT NO. 2	ISOLATED DC	NO. 3
WARN LT TEST & ANNUN CONT NO. 3	ISOLATED DC	NO. 3
LH AILERON SYSTEM NO. 1	MAIN DC NO. 1	NO. 4
LH AILERON SYSTEM NO. 2	MAIN DC NO. 2	NO. 4
RH AILERON SYSTEM NO. 1	MAIN DC NO. 1	NO. 4
RH AILERON SYSTEM NO. 2	MAIN DC NO. 2	NO. 4
LH AILERON IND	MAIN DC NO. 2	NO. 4
RH AILERON IND	MAIN DC NO. 2	NO. 4
AILERON TRIM POS IND	MAIN DC NO. 1	NO. 4
HYDRAULIC SYSTEM NO. 3 - NO. 1 PUMP CONT	MAIN DC NO. 1	NO. 4
HYDRAULIC SYSTEM NO. 3 - NO. 2 PUMP CONT	MAIN DC NO. 2	NO. 4

LOT'S CONTROL WHEEL TO NEUTRAL POSITION AS INDI-
INDEX MARKS ON WHEEL HUBS ALIGNED WITH SCRIBE MARKS
OF CONTROL COLUMNS.

CAUTION

G OR DISENGAGING THREE PHASE CIRCUIT BREAKERS
ELECTRICAL SYSTEM ENERGIZED COULD RESULT IN
O MOTORS BY OVERLOADING ONE OF THE MOTOR
ALWAYS VERIFY THAT ELECTRICAL POWER IS OFF BE-
AGING OR DISENGAGING CIRCUIT BREAKERS THAT
SWITCHED POWER DIRECTLY TO THREE PHASE MOTORS.

AT CIRCUIT BREAKERS LISTED IN TABLE 4-1B ARE CLOSED.

AT SWITCHES ARE POSITIONED ACCORDING TO TABLE 4-1C.

re 2. Functional Circuit Breakers

BREAKER NAME	BUS	FLT. ENGR. CKT. BKR. PNL.
PHASE A	MAIN AC NO. 1	NO. 1
PUMP NO. 1 PWR PHASE B	MAIN AC NO. 1	NO. 1
PUMP NO. 1 PWR PHASE C	MAIN AC NO. 1	NO. 1
PHASE A	MAIN AC NO. 3	NO. 1
PUMP NO. 2 PWR PHASE B	MAIN AC NO. 3	NO. 1
PUMP NO. 2 PWR PHASE C	MAIN AC NO. 3	NO. 1
PHASE A	ESSEN AC NO. 1	NO. 2
	ISOLATED DC	NO. 3
	ISOLATED DC	NO. 3
	ISOLATED DC	NO. 3
ANNUN CONT	ISOLATED DC	NO. 3
ANNUN CONT	ISOLATED DC	NO. 3
	MAIN DC NO. 1	NO. 4
	MAIN DC NO. 2	NO. 4
	MAIN DC NO. 1	NO. 4
	MAIN DC NO. 2	NO. 4
	MAIN DC NO. 2	NO. 4
	MAIN DC NO. 2	NO. 4
IND	MAIN DC NO. 1	NO. 4
M NO. 3-	MAIN DC NO. 1	NO. 4
M -	MAIN DC NO. 2	NO. 4

Figure 3. Preliminary Control Settings

CONTROL NAME	SETTING	LOCATION
RIGHT AILERON SYS 1	NORMAL	PILOT'S FORWARD OVERHEAD PANEL
RIGHT AILERON SYS 2	NORMAL	PILOT'S FORWARD OVERHEAD PANEL
LEFT AILERON SYS 1	NORMAL	PILOT'S FORWARD OVERHEAD PANEL
LEFT AILERON SYS 2	NORMAL	PILOT'S FORWARD OVERHEAD PANEL

EFFECTIVITY

1. AF63-8075 THROUGH 63-8077 IF NOT MODIFIED BY ECP LH-C141-100-181K AND AF63-8078 THROUGH 63-8087 IF NOT MODIFIED BY T.O. 1C-141A-616.
2. AF61-2775 THROUGH 61-2779, AF63-8075 THROUGH 63-8077 IF MODIFIED BY ECP LH-C141-100-181K, AF63-8078 THROUGH 63-8087 IF MODIFIED BY T.O. 1C-141A-616, AND AF63-8088 AND UP.
3. AF61-2775 THROUGH 61-2779 IF NOT MODIFIED BY T.O. 1C-141A-788
   AF63-8075 THROUGH 63-8077 IF NOT MODIFIED BY T.O. 1C-141A-788 & ECP LH-C141-100-181K
   AF63-8078 THROUGH 63-8079 IF NOT MODIFIED BY T.O. 1C-141A-788 & T.O. 1C-141A-616
   AF63-8081 THROUGH 63-8078 IF NOT MODIFIED BY T.O. 1C-141A-788 & T.O. 1C-141A-616
   AF63-8080 THROUGH 63-8078 IF NOT MODIFIED BY T.O. 1C-141A-788 & T.O. 1C-141A-616
   AF63-8082 THROUGH 63-8087 IF NOT MODIFIED BY T.O. 1C-141A-788 & T.O. 1C-141A-616
4. AF61-2775 THROUGH 61-2779 IF MODIFIED BY T.O. 1C-141A-788
   AF63-8075 THROUGH 63-8077 IF MODIFIED BY T.O. 1C-141A-788 & ECP LH-C141-100-181K
   AF63-8078 THROUGH 63-8079 IF MODIFIED BY T.O. 1C-141A-788 & T.O. 1C-141A-616
   AF63-8081 THROUGH 63-8079 IF MODIFIED BY T.O. 1C-141A-788 & T.O. 1C-141A-616
   AF63-8080 THROUGH 63-8079 IF MODIFIED BY T.O. 1C-141A-788 & T.O. 1C-141A-616
   AF63-8082 THROUGH 63-8087 IF MODIFIED BY T.O. 1C-141A-788 & T.O. 1C-141A-616
   AF 63-8088 AND UP
5. TERMINAL STRIPS INSTALLED IN AF 63-8075 AND UP. LEADS ARE WIRED STRAIGHT THROUGH IN AF61-2775 THROUGH 61-2779.
6. AF 63-8075 THROUGH 63-8077 IF NOT MODIFIED BY ECP LH-C141-100-181K
   AF 63-8078 THROUGH 63-8087 IF NOT MODIFIED BY T.O. 1C-141A-616
7. AF 61-2775 THROUGH 61-2779 IF MODIFIED BY ECP LH-C141-100-181K
   AF63-8075 THROUGH 63-8077 IF MODIFIED BY ECP LH-C141-100-181K
   AF63-8078 THROUGH 63-8087 IF MODIFIED BY T.O. 1C-141A-616
   AF63-8088 AND UP
8. AF61-2775 THROUGH 61-2779, AF63-8075 THROUGH 63-8077 IF MODIFIED BY ECP LH-C141-100-181K, AF63-8078 THROUGH 63-8087 IF MODIFIED BY T.O. 1C-141A-616, AND AF63-8088 AND UP

Figure A-1 Aileron Control and Trim System Preliminary Information Sheet

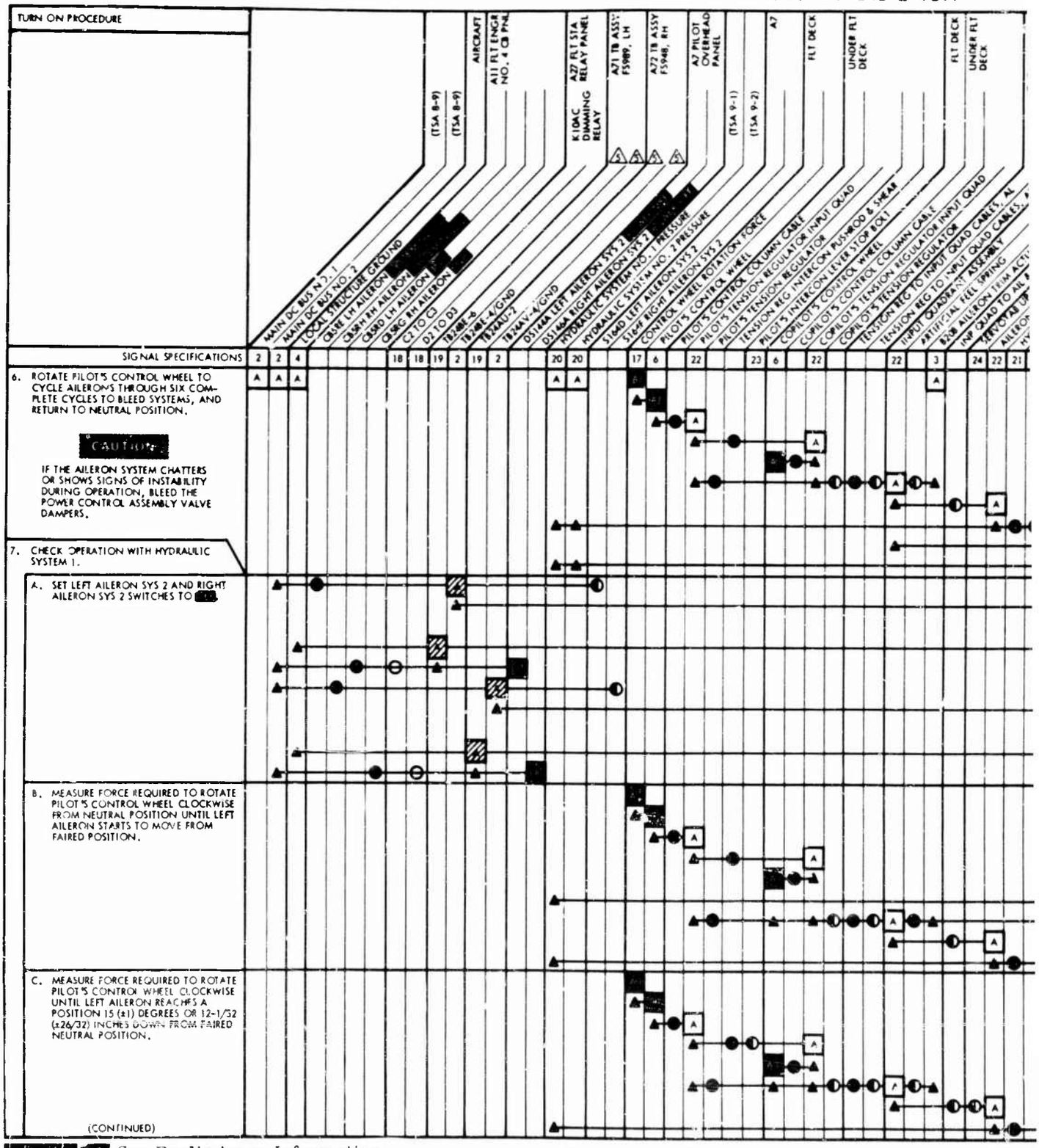
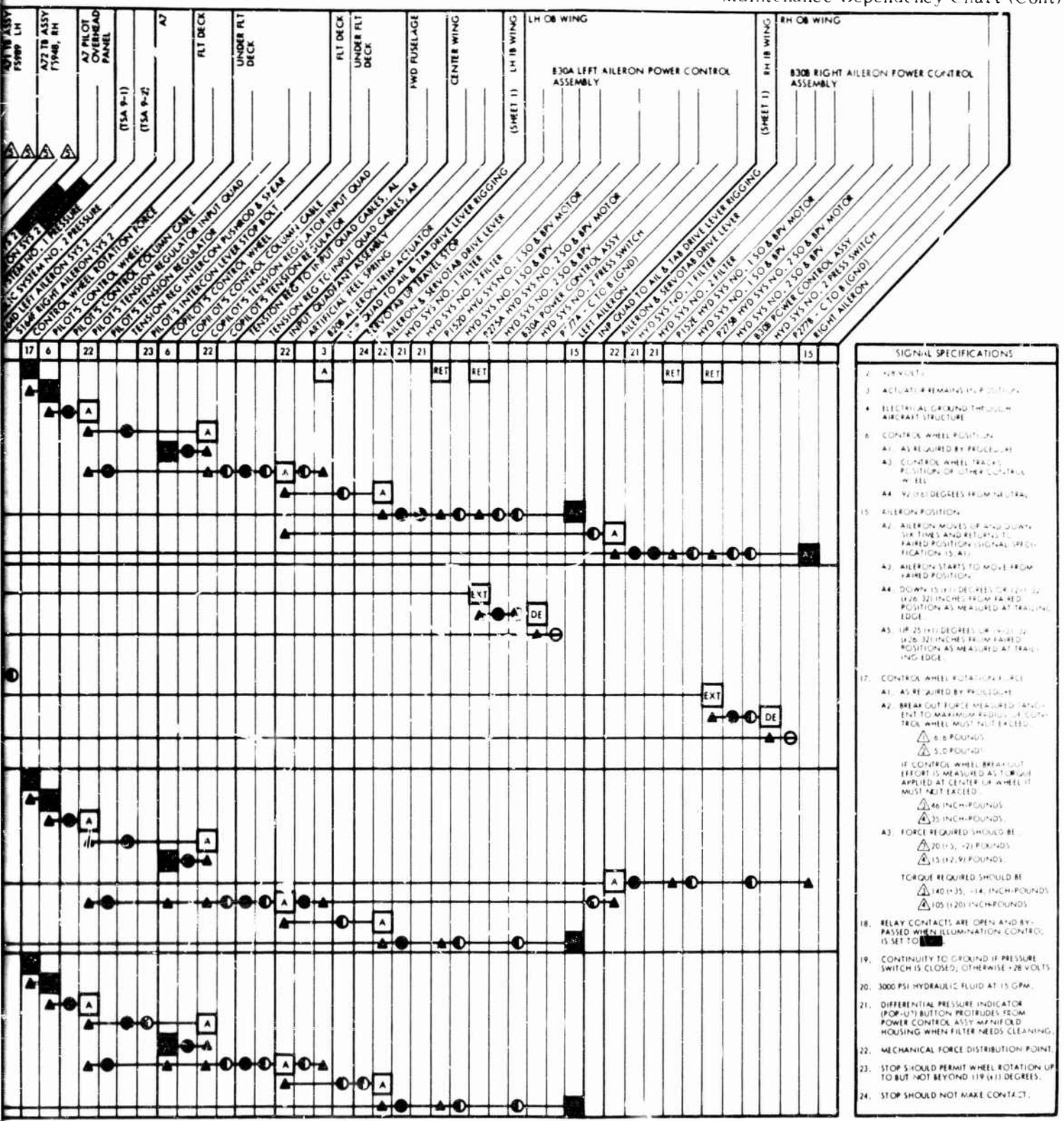


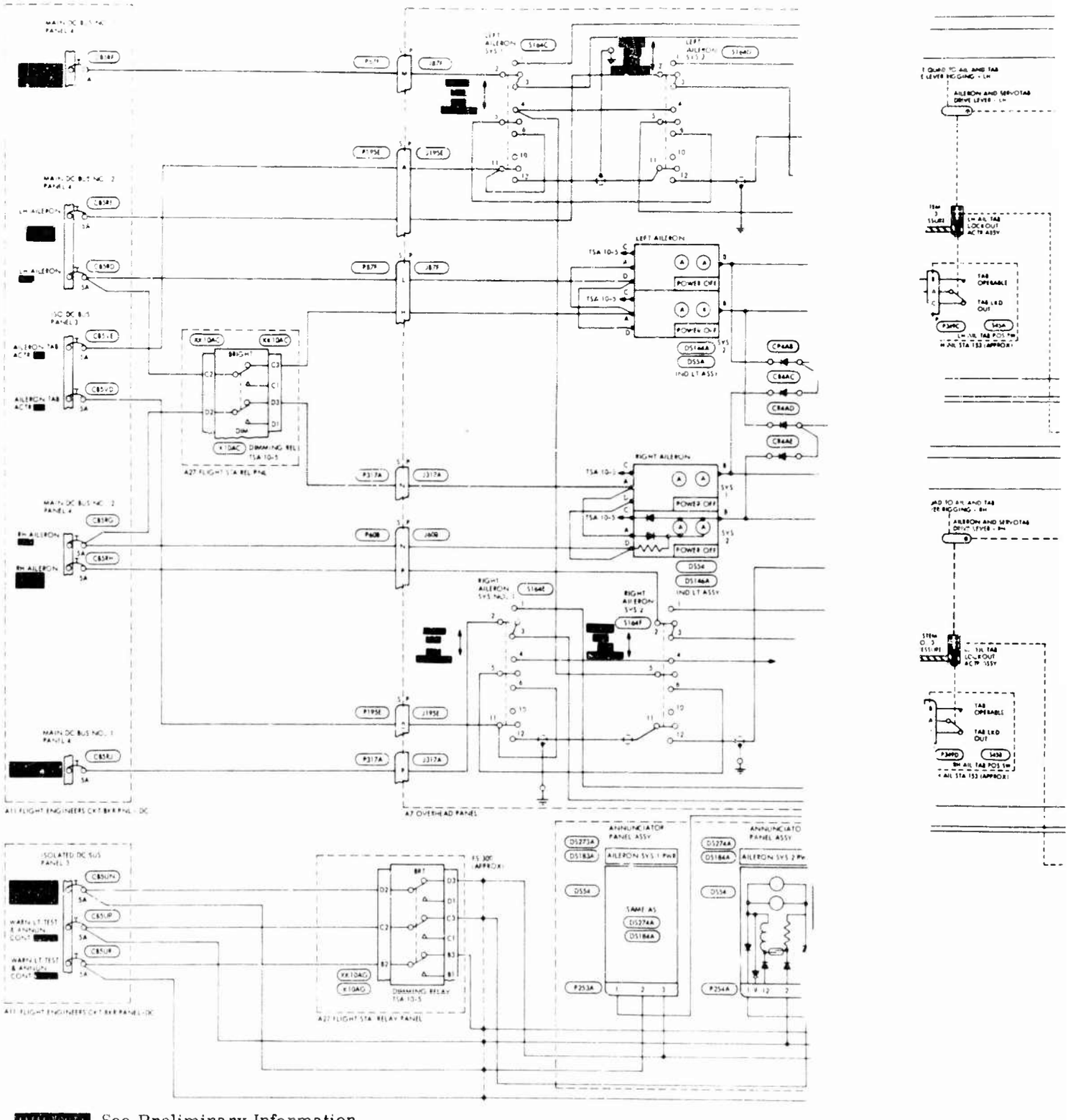
Figure 4. Aileron Control & Trim System MDC (S

A



re 4. Aileron Control & Trim System MDC (Sheet 3 of 9)

Figure A-2 Aileron Control and Trim System Maintenance Dependency Chart



CHANGE NOTICE See Preliminary Information
21 Apr 68

Figure 5. Aileron Control & Trim System Schematic Dia

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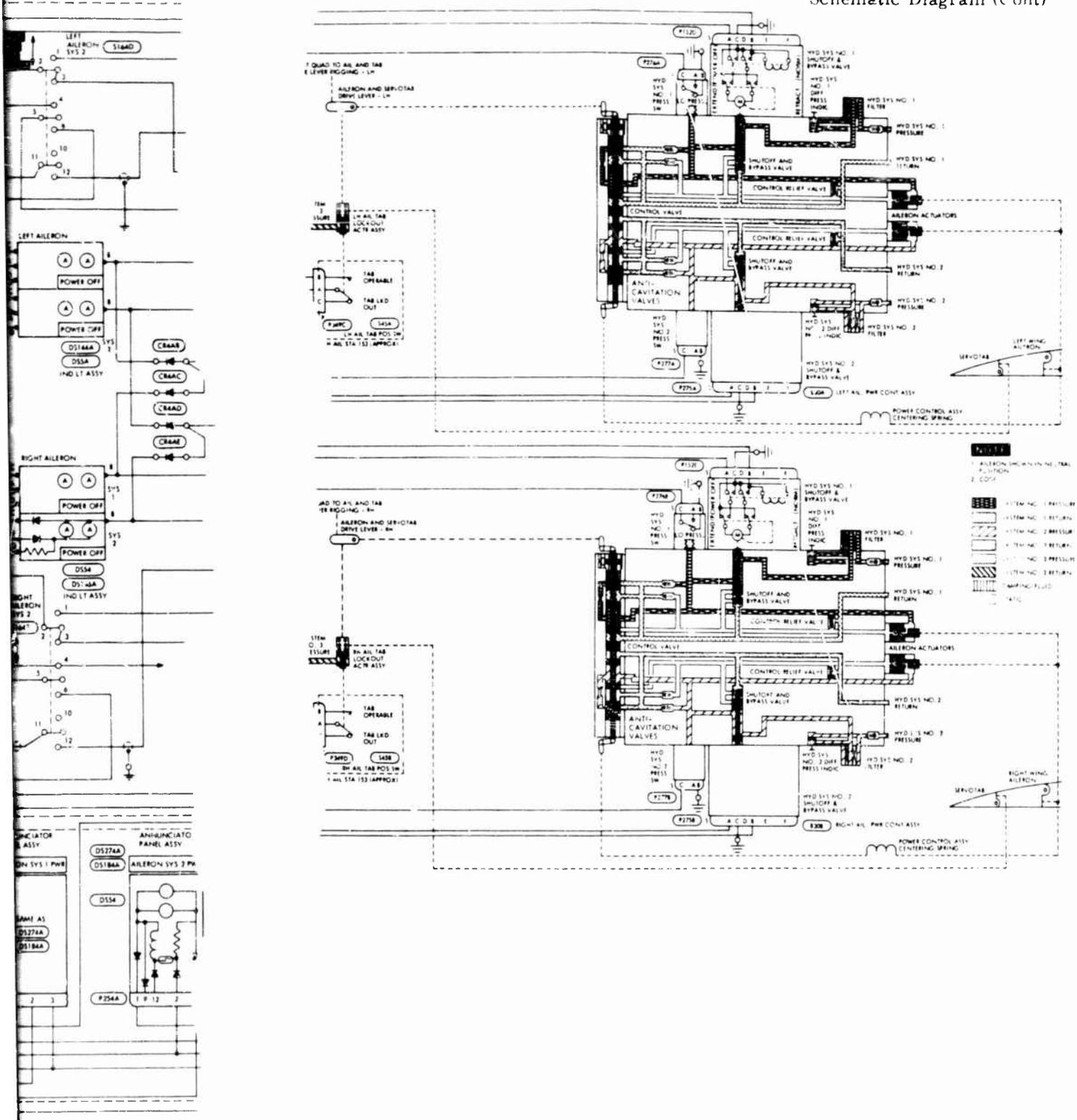
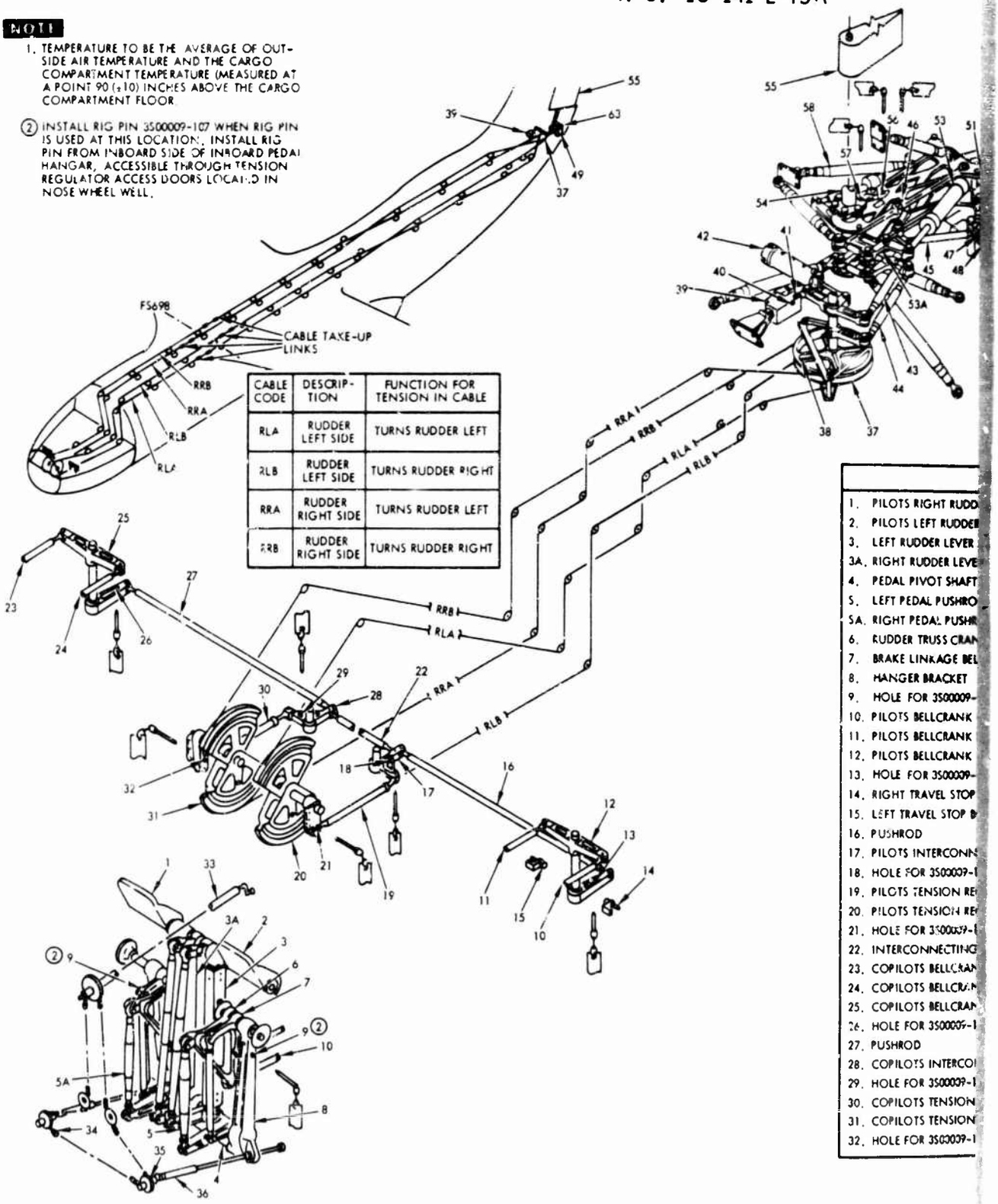


Aileron Control & Trim System Schematic Diagram Figure A-3

Aileron Control and Trim System Schematic Diagram



CHANGE 11, See Preliminary Information
21 Apr 68

Figure 6. Rudder Control & Trim System Parts Loca

Figure

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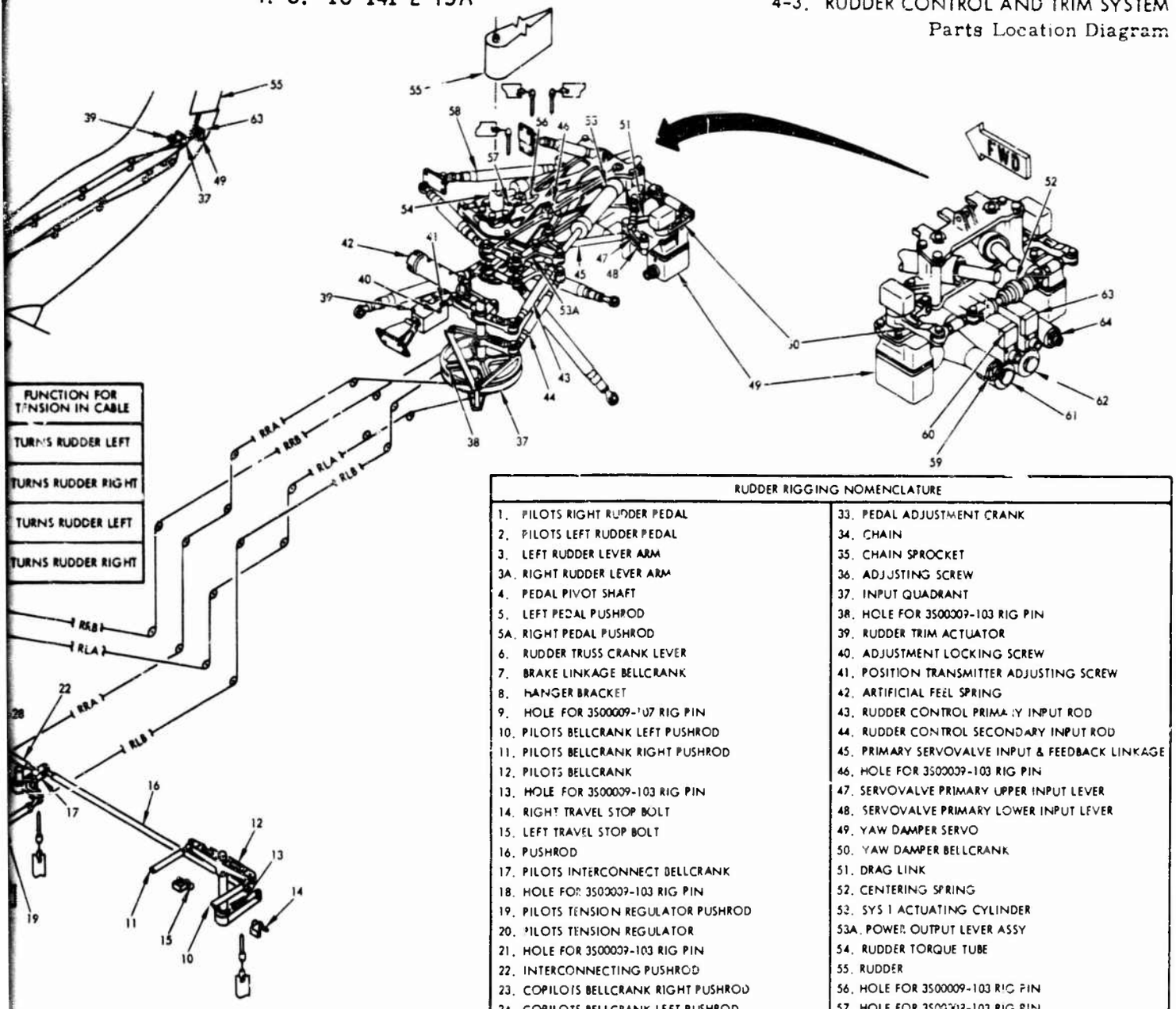

RUDDER RIGGING NOMENCLATURE	
1. PILOTS RIGHT RUDDER PEDAL	33. PEDAL ADJUSTMENT CRANK
2. PILOTS LEFT RUDDER PEDAL	34. CHAIN
3. LEFT RUDDER LEVER ARM	35. CHAIN SPROCKET
3A. RIGHT RUDDER LEVER ARM	36. ADJUSTING SCREW
4. PEDAL PIVOT SHAFT	37. INPUT QUADRANT
5. LEFT PEDAL PUSHROD	38. HOLE FOR 3500009-103 RIG PIN
5A. RIGHT PEDAL PUSHROD	39. RUDDER TRIM ACTUATOR
6. RUDDER TRUSS CRANK LEVER	40. ADJUSTMENT LOCKING SCREW
7. BRAKE LINKAGE BELLCRANK	41. POSITION TRANSMITTER ADJUSTING SCREW
8. HANGER BRACKET	42. ARTIFICIAL FEEL SPRING
9. HOLE FOR 3500009-107 RIG PIN	43. RUDDER CONTROL PRIMARY INPUT ROD
10. PILOTS BELLCRANK LEFT PUSHROD	44. RUDDER CONTROL SECONDARY INPUT ROD
11. PILOTS BELLCRANK RIGHT PUSHROD	45. PRIMARY SERVOVALVE INPUT & FEEDBACK LINKAGE
12. PILOTS BELLCRANK	46. HOLE FOR 3500009-103 RIG PIN
13. HOLE FOR 3500009-103 RIG PIN	47. SERVOVALVE PRIMARY UPPER INPUT LEVER
14. RIGHT TRAVEL STOP BOLT	48. SERVOVALVE PRIMARY LOWER INPUT LEVER
15. LEFT TRAVEL STOP BOLT	49. YAW DAMPER SERVO
16. PUSHROD	50. YAW DAMPER BELLCRANK
17. PILOTS INTERCONNECT BELLCRANK	51. DRAG LINK
18. HOLE FOR 3500009-103 RIG PIN	52. CENTERING SPRING
19. PILOTS TENSION REGULATOR PUSHROD	53. SYS 1 ACTUATING CYLINDER
20. PILOTS TENSION REGULATOR	53A. POWER OUTPUT LEVER ASSY
21. HOLE FOR 3500009-103 RIG PIN	54. RUDDER TORQUE TUBE
22. INTERCONNECTING PUSHROD	55. RUDDER
23. COPILOTS BELLCRANK RIGHT PUSHROD	56. HOLE FOR 3500009-103 RIG PIN
24. COPILOTS BELLCRANK LEFT PUSHROD	57. HOLE FOR 3500009-103 RIG PIN
25. COPILOTS BELLCRANK	58. SUPPORT BAR
26. HOLE FOR 3500009-103 RIG PIN	59. SYS 1 LOAD LIMIT PILOT VALVE SOLENOID
27. PUSHROD	60. SYS 1 SHUTOFF AND BYPASS VALVE
28. COPILOTS INTERCONNECT BELLCRANK	61. SYS 1 FILTER
29. HOLE FOR 3500009-103 RIG PIN	62. SYS 2 FILTER
30. COPILOTS TENSION REGULATOR PUSHROD	63. SYS 2 SHUTOFF & BYPASS VALVE
31. COPILOTS TENSION REGULATOR	64. SYS 2 LOAD LIMIT PILOT VALVE SOLENOID
32. HOLE FOR 3500009-103 RIG PIN	65. RUDDER POWER CONTROL ASSY

Figure 6. Rudder Control & Trim System Parts Location Diagram

Figure A-4 Parts Location Diagram

FUNCTIONAL DESCRIPTION

GENERAL. (See Fig. 6) Trimming the aircraft about the pitch axis is accomplished by the pitch trim system. The pitch trim system includes the horizontal stabilizer, the horizontal stabilizer actuator, electro-hydraulic trim control system, manual-hydraulic trim control system, electrical trim control system, electrical power circuits, and the horizontal stabilizer position indication system. The horizontal stabilizer is the pitch trim control surface. The rear spar of the horizontal stabilizer is attached, by pivots, to the top of the vertical stabilizer. Pitch trim is accomplished through angular rotation of the control surface around the pivot axis to change the angle of attack of the control surface. Upward movement of the horizontal stabilizer leading edge produces nose-down trim of aircraft attitude, and downward movement of the stabilizer leading edge produces nose-up trim. The pitch trim system supplements the elevator control system but is completely independent of elevator control surface movements. The angular trim range of the horizontal stabilizer is approximately 4 degrees above the neutral position to 12.5 degrees below neutral. Pitch trim corrections may be made by operating electro-hydraulic trim control switches located on the pilot's or copilot's control wheels, manual-hydraulic control levers at the pilots' center console. Electrical signals from the autopilot or Mach trim compensator systems can produce trim corrections when these systems are operating. A disconnect button, situated on the inboard grip of each pilot's control wheel, is provided to disengage the trim control systems. An autopilot disconnect button situated on the outboard grip of each pilot's control wheel, is used to disengage the automatic pitch trim mode of the autopilot. A reset switch on the center console can be operated to the "ELEC" position to reset the electrical trim control system and to the "ELEC HYD" position to reset the electro-hydraulic trim control system after a control wheel disconnect switch has disconnected these systems. On aircraft with stall prevention systems installed, electro-hydraulic and electric nose-up trim capability is removed when the control column shakers are operating to indicate that the aircraft is approaching a stall condition.

HORIZONTAL STABILIZER ACTUATOR. The horizontal stabilizer actuator, a linear screwjack type actuator, is installed in a vertical plane. The upper attaching fitting is bolted to the forward spar of the horizontal stabilizer, and the lower attach fitting is bolted to a shelf at waterline 505 on the forward spar of the vertical stabilizer. Two completely independent drive systems, the electromechanical and hydromechanical drive units, are used for pitch trim control. The electromechanical drive unit at the top of the actuator assembly, is driven by an electric motor. This assembly, consisting of a gear train and dual clutch arrangement, turns the jackscrew. The hydromechanical unit is at the lower end of the actuator assembly and is driven by a hydraulic motor. This assembly consists of a gear train and a rotating nut which is turned by the gear train. The rotating nut, through which the jackscrew is threaded, is restrained from vertical movement by thrust bearings. Pitch trim is accomplished by rotating the screw within the nut (electromechanical drive) or by rotating the nut around the jackscrew (hydromechanical drive). Either mode of operation will cause the jackscrew to extend or retract.

ELECTRO-HYDRAULIC TRIM CONTROL SYSTEM. (See Fig. 6) The hydromechanical drive unit of the stabilizer actuator can be controlled by either the electro-hydraulic trim control system or by the manual-hydraulic trim control system since both systems are connected to the flow control valve of the hydromechanical drive by a summing bar linkage. Input motions from either trim control system can be transferred to the valve lever by the summing bar linkage while the other trim control system remains static. Components included in the electro-hydraulic trim control system are: dual switches on the outboard grip of each pilot control wheel, a solenoid-controlled hydraulic actuator connected to the summing bar linkage, a Mach trim compensator disengage relay, an autopilot disengage relay, and three stabilizer position limit switches. The pair of trim switches on either control wheel can be used to operate the electro-hydraulic trim control system. Simultaneous operation of both switches of either pair to the "NOSE UP" or "NOSE DN" positions, provides power and a ground connection to the respective solenoid in the hydraulically operated control valve actuator. It is impossible for the set of switches on one control wheel to electrically override the switches on the other control wheel. As the control valve actuator extends or retracts, the summing bar linkage and the control valve are repositioned to drive the stabilizer to a corresponding position. Operation of the control wheel trim switches, in either direction, also de-energizes the hydraulic shutoff valve, on the stabilizer actuator to the open position and disengages the autopilot and Mach trim compensator systems. On aircraft provided with a stall prevention system, the power and ground circuits to the nose up solenoids of the control valve actuator are routed through the pilot's and copilot's stall prevention control relays. When the stall prevention system senses an impending stall condition, a warning signal energizes these relays to interrupt the power and ground circuits to remove nose up trim capability. There are six limit switch assemblies mounted in the vertical stabilizer and connected by mechanical linkage to the horizontal stabilizer. Three of these switch assemblies include two switches: one for the electro-hydraulic trim control system circuits and one for the manual-hydraulic trim control system circuits. The limit switches associated with the electro-hydraulic trim control switches, when actuated, interrupt the power circuit to the corresponding control valve actuator solenoids to stop stabilizer actuator operation. The nose-down limit switch actuates when the horizontal stabilizer reaches the 4 degrees leading edge above neutral position. One of the nose-up limit switches actuates when the horizontal stabilizer reaches the 8 degrees leading edge below neutral position if the flaps are fully retracted. If the flaps are not fully retracted, the flap position relay transfers the nose-up power circuit to the 12.5 degrees nose-up limit switch circuit, which actuates when the stabilizer leading edge reaches a position 12.5 degrees below the neutral position.

MANUAL-HYDRAULIC TRIM CONTROL SYSTEM. Each pilot is provided with a pitch trim control lever. These levers, located at the center console, are connected to the stabilizer actuator summing bar linkage by mechanical linkage and cables. The summing bar linkage permits either the electro-hydraulic or the manual-hydraulic control system to introduce control motions to the stabilizer actuator flow control valve while the other trim control system remains static. Each control lever has a switch that is actuated to the open position when the fore and aft sections of the control lever handle are squeezed together. If either lever switch is open, the hydraulic shutoff valve at the stabilizer actuator is de-energized to the open position and pressure is admitted to the flow control valve. The displacement of the control levers in either direction from the neutral positions results in a proportional displacement of the flow control valve. The rate of stabilizer actuation is therefore proportional to the amount of control lever displacement. Operating either control lever switch also de-energizes the pitch trim disengage relay of the autopilot and Mach trim systems to disconnect these systems from the stabilizer actuator.

NOTE

The manual pitch trim control levers may jerk fore or aft for short distances when the pitch trim control system is operated with the electro-hydraulic trim switches on either control wheel. This feedback response is due to linkage geometry and component tolerances and does not impair system operation.

ELECTRICAL TRIM CONTROL SYSTEM. The electromechanical drive unit of the stabilizer actuator is controlled by the electrical trim control system, and by the autopilot or Mach trim compensator system if these systems are operating. The electrical trim control system includes: dual "ELEC PITCH TRIM" control switches on the center console, two clutch relays, a transfer relay, two counter-rotating clutches, three stabilizer position limit switches, and a trim disconnect relay. Also the trim disconnect switches on the pilots' control wheels and the trim reset switch at the center console are shared with the electro-hydraulic trim control system. Simultaneous operation of the two electric pitch trim switches to the "NOSE UP" or "NOSE DN" positions connects power and a groun
relay corresponding to the direction c
clutch relay functions to connect an
the corresponding actuator clutch and
signal to the Mach trim compensator
routed through a transfer relay. The
control of the trim system from pilot
disengage signal to the Mach trim cor
autopilot system is engaged. The aut
power and a ground circuit for trim op
system then furnishes power and a gro
ation. The autopilot is disengaged wi
of the hydraulic trim control systems.
associated with the electrical trim cor
in the vertical stabilizer and actuated
the horizontal stabilizer. The nose-d
when the horizontal stabilizer leading
4 degrees above the neutral position t
circuit to the nose-down clutch. If th
one of the nose-up limit switches actu
leading edge reaches a position 8 degr
position to interrupt the nose-up clutch
flaps are not fully retracted, the transf
circuit of the nose-up clutch circuit th
that actuates when the stabilizer leadi
below the neutral position. The Mach
is connected to the electric trim contro
lays. When connected, the Mach trim
and a ground circuit for the motor clut
Mach trim system is disengaged when t
when the pilot energizes the clutch rel
energizes one of the hydraulic trim cor
the trim disconnect switches, one on th
pilot's control wheel, can be used to d
hydraulic trim control system and the e
tem. The switch disconnects the electri
pleting a power circuit to the trim disc
electrical trim disengage relay. Actua
relay interrupts the power circuits to th
rupts the power circuits to the electric
actuator, and also disconnects the auto
compensator systems. Operation of the
"ELEC" position connects power to the
tric trim disengage relay to return the
ating position. Both disconnect switch
are momentary-contact type switches.
disengage relay solenoids are normally
craft provided with a stall prevention sy
ground circuits of the stabilizer actuato
routed through the pilot's and copilot's
relays. When a control column shaker
cate an approaching stall condition, th
cuits to the nose-up clutch are interrupt
trim capability.

ELECTROMECHANICAL DRIVE UNIT O
STABILIZER ACTUATOR. The electrom
driven by a 3-phase, 400-cycle AC mat
the essential AC bus. The motor runs c
connected by a TRIM DISC switch on th
Two 28-volt, magnetically operated clu
site directions, engage the motor to the
of one clutch extends the jackscrew, an
other clutch retracts the jackscrew. Or
engaged at any one time. A dual trim s
provided on the pilot's center console fo
corrections. Both switches have to be a
to complete the electrical circuit. One
and the other switch supplies 28 volts fr
These switches are spring-loaded to the
mentarily in the "NOSE UP" or "NOSE
correction signals also come from the au
compensator systems. These signals also
extend or retract clutch. Since this is a
pared with the hydromechanical drive u
setting can be made for longitudinal con

A

tion to the respective solenoid in the
rol valve actuator. It is impossible
e control wheel to electrically over-
r control wheel. As the control
racts, the summing bar linkage and
tioned to drive the stabilizer to o
eration of the control wheel trim
, also de-energizes the hydraulic
er actuator to the open position and
Mach trim compensator systems. On
prevention system, the power and
solenoids of the control valve ac-
pilot's and copilot's stall prevention
ll prevention system senses on im-
ming signal energizes these relays
round circuits to remove nose up trim
it switch assemblies mounted in the
ted by mechanical linkage to the
of these switch assemblies include
ctro-hydraulic trim control system
ual-hydraulic trim control system cir-
ciated with the electro-hydraulic
ctuated, interrupt the power circuit
valve actuator solenoids to stop stabi-
nose-down limit switch actuates
r reaches the 4 degrees leading edge
of the nose-up limit switches ac-
bilizer reaches the 8 degrees lead-
ion if the flaps are fully retracted. If
ted, the flap position relay transfers
the 12.5 degree nose-up limit switch
the stabilizer leading edge reaches a
the neutral position.

CONTROL SYSTEM. Each pilot is
ntrol lever. These levers, located
nnected to the stabilizer actuator
nical linkage and cables. The
either the electro-hydraulic or the
tem to introduce control motions to
control valve while the other trim
. Each control lever has a switch
position when the fore and aft sections
re squeezed together. If either lever
shutoff valve at the stabilizer act-
open position and pressure is admit-
. The displacement of the control
n the neutral positions results in a
the flow control valve. The rate of
re proportional to the amount of
Operating either control lever
pitch trim disengage relay of the
ms to disconnect these systems from

T.

control levers may jerk
tances when the pitch trim
ted with the electro-hy-
n either control wheel.
is due to linkage geometry
ces and does not impair

L SYSTEM. The electromechanical
tuator is controlled by the electri-
by the autopilot or Mach trim con-
ns are operating. The electrical
dual "ELEC PITCH TRIM" control
e, two clutch relays, a transfer re-
tches, three stabilizer position
connect relay. Also the trim dis-
t' control wheels and the trim re-
le are shared with the electro-
. Simultaneous operation of the two
h the "NOSE UP" or "NOSE DN"

positions connects power and a ground connection to the clutch relay corresponding to the direction of switch operation. The clutch relay functions to connect an electrical power supply to the corresponding actuator clutch and to connect a disengage signal to the Mach trim compensator system. Both circuits are routed through a transfer relay. The transfer relay switches the control of the trim system from pilot to autopilot and directs a disengage signal to the Mach trim compensator system when the autopilot system is engaged. The autopilot system then furnishes power and a ground circuit for trim operation. The autopilot system then furnishes power and a ground circuit for trim operation. The autopilot is disengaged when the pilot energizes one of the hydraulic trim control systems. The three limit switches associated with the electrical trim control system are mounted in the vertical stabilizer and actuated by linkage connected to the horizontal stabilizer. The nose-down limit switch actuates when the horizontal stabilizer leading edge reaches a position 4 degrees above the neutral position to interrupt the ground circuit to the nose-down clutch. If the flaps are fully retracted, one of the nose-up limit switches actuates when the stabilizer leading edge reaches a position 8 degrees below the neutral position to interrupt the nose-up clutch ground circuit. If the flaps are not fully retracted, the transfer relay routes the ground circuit of the nose-up clutch circuit through the limit switch that actuates when the stabilizer leading edge is 12.5 degrees below the neutral position. The Mach trim compensator system is connected to the electric trim control system at the clutch relays. When connected, the Mach trim system furnishes a power and a ground circuit for the motor clutch being operated. The Mach trim system is disengaged when the autopilot is engaged, when the pilot energizes the clutch relay, and when the pilot energizes one of the hydraulic trim control systems. Either of the trim disconnect switches, one on the inboard grip of each pilot's control wheel, can be used to disconnect the electro-hydraulic trim control system and the electric trim control system. The switch disconnects the electrical trim system by completing a power circuit to the trim disengage solenoid of the electrical trim disengage relay. Actuation of this self-latching relay interrupts the power circuits to the clutch relays, interrupts the power circuits to the electric motor of the stabilizer actuator, and also disconnects the autopilot and the Mach trim compensator systems. Operation of the trim reset switch to the "ELEC" position connects power to the reset coil of the electric trim disengage relay to return the relay to the normal operating position. Both disconnect switches and the reset switch are momentary-contact type switches. Both of the electric trim disengage relay solenoids are normally de-energized. On aircraft provided with a stall prevention system, the power and ground circuits of the stabilizer actuator nose-up clutch are routed through the pilot's and copilot's stall prevention control relays. When a control column shaker starts operating to indicate an approaching stall condition, the power and ground circuits to the nose-up clutch are interrupted to remove nose-up trim capability.

ELECTROMECHANICAL DRIVE UNIT OF THE HORIZONTAL STABILIZER ACTUATOR. The electromechanical drive unit is driven by a 3-phase, 400-cycle AC motor that is powered from the essential AC bus. The motor runs continually until disconnected by a TRIM DISC switch on the pilot's control wheels. Two 28-volt, magnetically operated clutches, rotating in opposite directions, engage the motor to the gear train. Engagement of one clutch extends the jackscrew, and engagement of the other clutch retracts the jackscrew. Only one clutch can be engaged at any one time. A dual trim switch arrangement is provided on the pilot's center console for electrical trim control corrections. Both switches have to be actuated simultaneously to complete the electrical circuit. One switch provides a ground and the other switch supplies 28 volts from the main DC bus. These switches are spring-loaded to the off position and are momentarily in the "NOSE UP" or "NOSE DOWN" positions. Trim correction signals also come from the autopilot and Mach trim compensator systems. These signals also energize the actuator extend or retract clutch. Since this is a slow rate unit as compared with the hydromechanical drive unit, a more precise trim setting can be made for longitudinal control.

4-2-2. PITCH TRIM SYSTEM
Functional Description

HYDROMECHANICAL DRIVE UNIT OF THE HORIZONTAL STABILIZER ACTUATOR. The hydromechanical drive unit is powered by a hydraulic motor using pressure from the No. 2 hydraulic system. A reduction gear drive, meshed to the motor output gear, turns the rotating nut which causes the jackscrew to move up or down. The maximum rate of trim change is approximately 5 times faster than electromechanical drive operation. The stabilizer can also be actuated manually for ground maintenance by engaging drive devices to drive sockets located on either gearbox. The speed and direction of motor rotation is controlled by means of the hydraulic flow control valve, which is located at the horizontal stabilizer trim actuator assembly.

HYDRAULIC FLOW CONTROL VALVE. The hydraulic flow control valve is attached to the horizontal stabilizer actuator assembly, is mechanically connected to the flow control valve actuator, and is connected by mechanical linkage and cables to the pilot's and copilot's trim levers. Built within the valve assembly is a 28-volt DC shutoff valve, a pressure line filter, and a filter clog indicator button. The flow control valve is a modulating type valve which controls the amount of hydraulic oil flow and the direction of flow to the hydraulic motor. When the valve spool is in the neutral position, the pressure port is blocked and both motor control ports are opened to system return.

HYDRAULIC SHUTOFF VALVE. The 28-volt DC, solenoid-operated hydraulic shutoff valve is a component of the stabilizer actuator hydromechanical drive unit. This valve is normally energized to the closed position by electrical power from the main DC bus No. 1. The valve is de-energized to the open position when the electro-hydraulic trim switches on one of the pilot's control wheels are operated to activate the electro-hydraulic trim control system. The valve is also de-energized to the open position when the fore and aft sections of either pilot's trim control lever are squeezed together.

DIRECTIONAL CONTROL SWITCHES. The manual-hydraulic trim control system is provided with two directional control switches, one up and one down, which are actuated by cams on the stabilizer actuator input cable quadrant. Electrical power for the hydraulic shutoff valve operation is routed through these normally-closed directional control switches and also the associated position limit switches. Rotation of the input quadrant in either direction opens the corresponding directional control switch to route power to hydraulic shutoff valve through the corresponding position limit switches.

HYDRAULIC FILTER. The hydraulic filter portion of the flow control valve assembly filters system pressure downstream from the shutoff and modulating sections of the valve assembly. The filter has a micronic filter element without a bypass feature. Should the filter element become dirty or clogged, a red indicator button will extend about 1/4 inch. The indicator button is located adjacent to the filter at the bottom of the flow control valve assembly.

HORIZONTAL STABILIZER TRIM LIMIT SWITCHES. The horizontal stabilizer trim limit switches are mounted on a bracket assembly which is attached to the vertical stabilizer. The limit switches are actuated by cams which are mechanically linked to the horizontal stabilizer. Movement of the stabilizer up or down rotates the cams, and the switch contacts will open when travel limits are reached. Six limit switch assemblies are used: three for the electro-hydraulic and manual-hydraulic trim control systems and three for the electrical trim control system. Each of the hydraulic system limit switch assemblies contains a switch for each of the hydraulic trim control systems. The limit switches are actuated at one of the trim range limits of approximately 4 degrees nose-down regardless of wing flap positions, 8 degrees nose-up if the flaps are fully retracted, or at 12.5 degrees nose-up if the flaps are not fully retracted. The limit switches associated with the electro-hydraulic trim control system, when actuated, interrupt the power circuit to the corresponding control valve actuator solenoids to stop stabilizer actuator operation. The limit switches associated with the manual-hydraulic trim control system, when actuated, connect power to the hydraulic shutoff valve solenoid to close the valve and stop horizontal stabilizer actuator operation. The limit switches associated with the electrical trim

Figure A-5 Pitch Trim System Functional Description

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11 SUPPLEMENTARY NOTES	12 SPONSORING MILITARY ACTIVITY
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13 ABSTRACT

This report describes the latest phase in the program to develop and evaluate PIMO (Presentation of Information for Maintenance and Operation), a job guide concept applied to maintenance. Between August 1968 and April 1969, a test was conducted at Charleston AFB, South Carolina, to determine the effectiveness of PIMO. Three immediate behavioral effects were expected: 1) reduction in maintenance time, 2) reduction in maintenance errors, and 3) allow usage of inexperienced technicians with no significant penalty. Experienced and inexperienced Air Force technicians performed maintenance on C-141A aircraft using PIMO Job Guides presented in audio-visual and booklet modes. Performance was measured in terms of time to perform and procedural errors. The performance was compared with the performance on the same jobs by a control group, i.e., experienced technicians performing in the normal manner. The following conclusions were drawn from the test results: 1) after initial learning trials, both experienced and inexperienced technicians using PIMO can perform error-free maintenance within the same time as experienced technicians performing in the normal manner, 2) inexperienced technicians perform as well as experienced technicians when both use PIMO, 3) there is no significant difference between audio-visual and booklet modes, 4) the users revealed an overwhelmingly positive reaction to PIMO, and 5) the performance improvements provide the capabilities to significantly improve system performance defined in terms of departure reliability, time-in-maintenance, and operational readiness. This report also presents a description of the recommended operational system, specifications and guidelines for PIMO format development, including troubleshooting.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Maintenance Aids, Improved Job-oriented Guides Aircraft Maintenance Troubleshooting Aids Field Test of Maintenance Aids Audio-visual Presentation, Maintenance Data Maintenance Dependency Charts, Preparation of PIMO, Programmed Information for Maintenance Technical Data, Reformatting of Technical Data, Specifications for Technical Orders, Comparison of (with PIMO) PIMO, Project Final Report						

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